ENGINEERING

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In this issue

TALKING TO AMERICANS:
WHERE THEIR
THINKING LEADS

NON-LINEAR
FORCED VIBRATIONS
OF
CIRCULAR DISCS

PRODUCTION OF
CURVED SAFETY GLASS

LUBRICATION OF
PLAIN BEARINGS
Reynolds'
Hydrodynamic Theory

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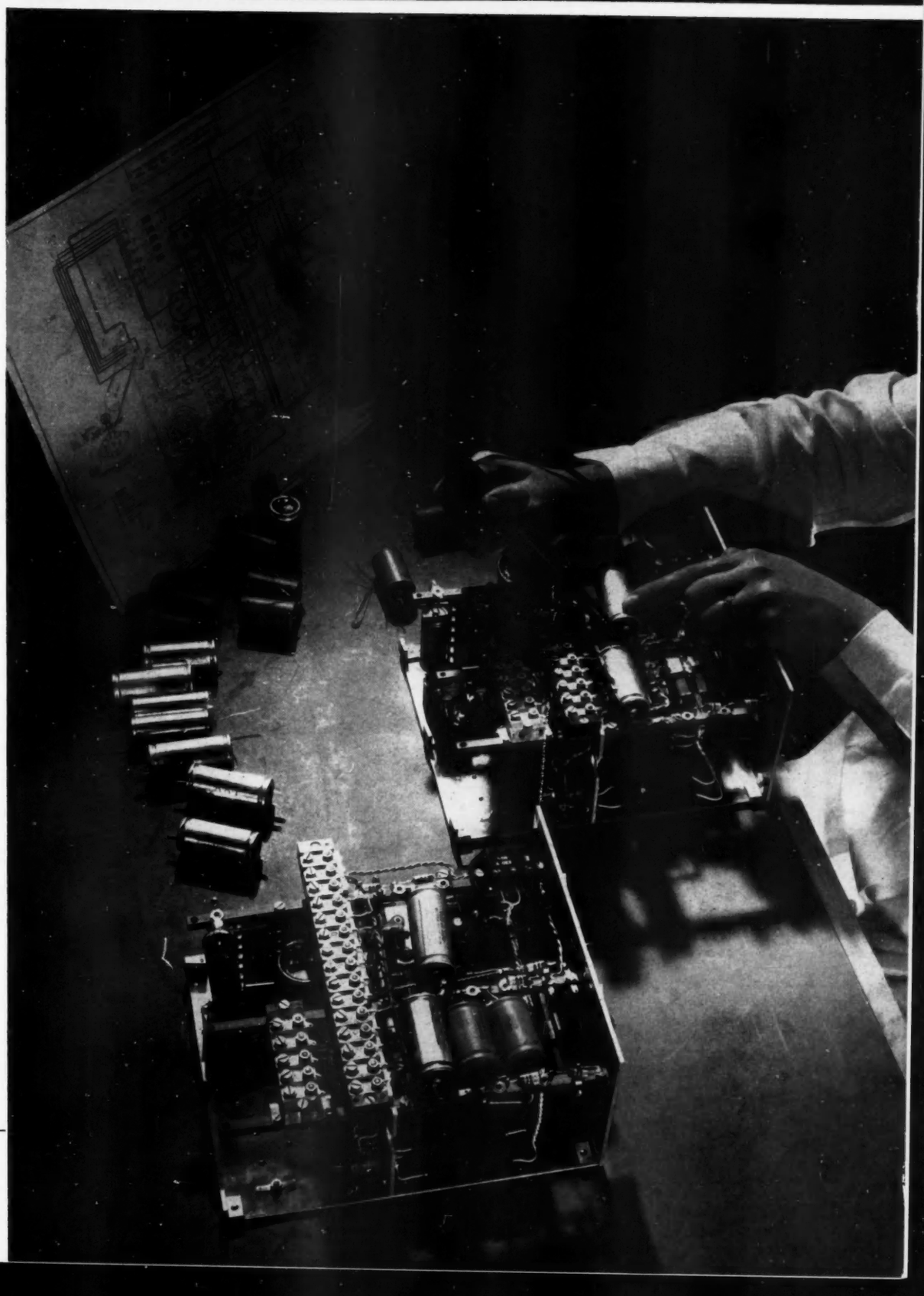
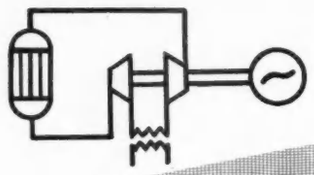
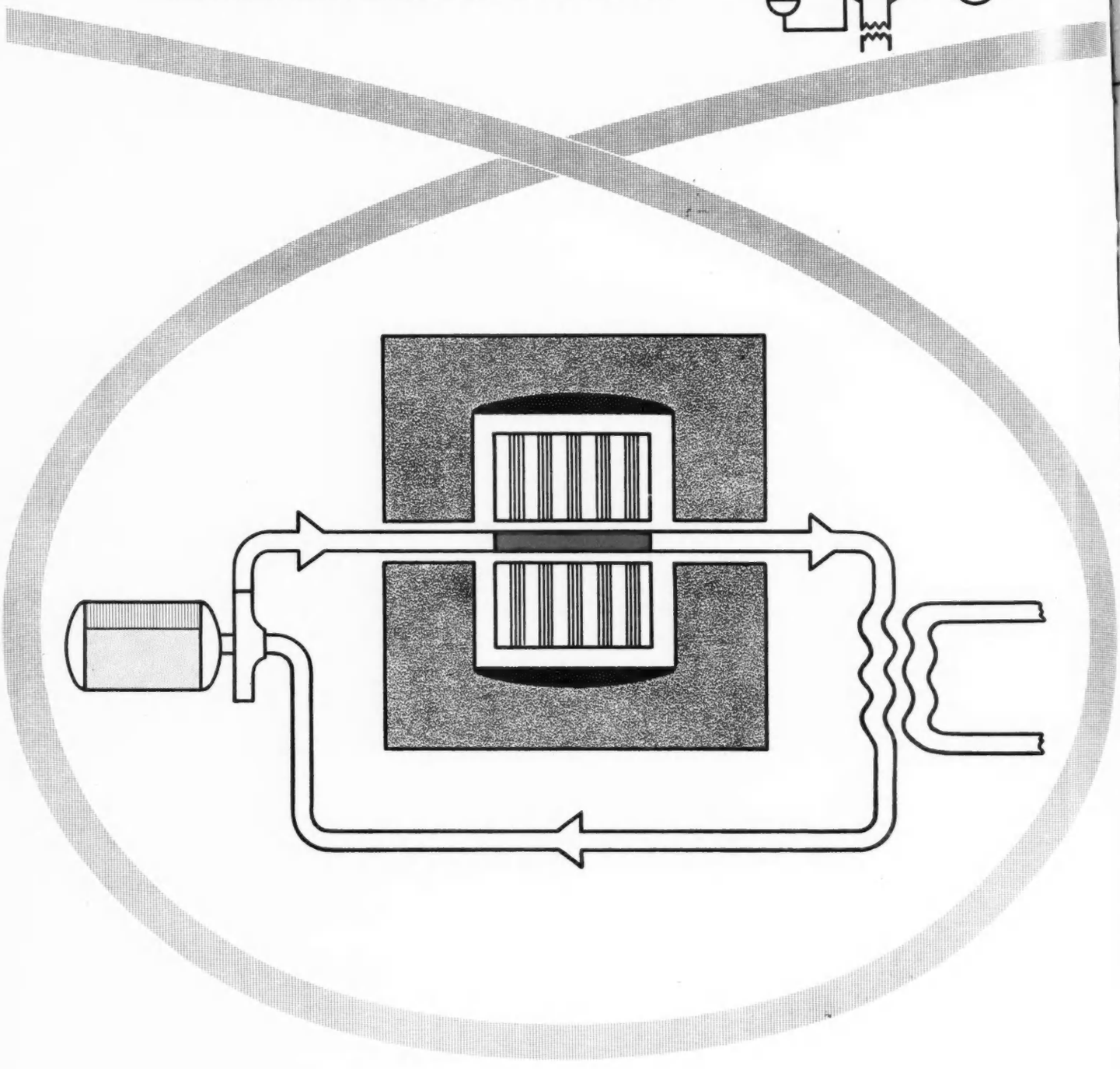


Soldering Operation

Towards the HTGCR—





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Contents

33 **Leading Article**
Purpose in Perspective

34 **Plain Words**

35 **Letters to the Editor**
Earning a Car in America
Accelerated Curing Tests on Concrete

39 **Companies in the News**

40 **Special Article**
Talking to Americans: America is still Going Places

44 **Atomic Review**
Water in Moderation

47 **Automobile Engineering**
German Miniature Car to be Made in England
Daimler Activity Increasing

48 **In Parliament**

57 **Book Review**
Henry Edward Armstrong, 1848-1937

57 **New Books**

57 **On the Shelf**

64 **Engineering at Home**
More Lines for TV?
Polythene Cold-Water Tubing Specification
Gun Microphone

34 **Management**
Weekly Survey

36 **Plant and Equipment**
Cleaning Bagasse
Institution of Highway Engineers
International Approach to Gearing
Compact Heavy-Duty Pneumatic/Hydraulic Ram
Aluminium Derrick for Mobile Prospecting Work
Portable Amplifier

38 **Metals and Materials**
Dunlop Rubber Compounding Factory
Saroy Toughened Plastics Sheet: Film
Bright Silver Electroplate
For Hot Electronics
British Standard for Galvanised Steel Sheet

46 **The Human Element**

49 **Research and Development**
Aspects of Welding: Research Work at Abington
Non Linear Forced Vibrations of Circular Discs: An Experimental Investigation

58 **Production**
Curved Safety Glass

59 **Design**
Lubrication of Plain Bearings: Applicability of Reynolds's Hydrodynamic Theory
Protecting Aircraft from Ice
Roller Clutch for Smaller Mechanisms
Olympus Type Test
Rolls-Royce Silence American Airliners

63 **Construction**
Heliport for London's South Bank
Forth Road Bridge: Tender for Superstructure Pending
Wood-Fibre Building Boards

Purpose in Perspective

Two dangers arise when we consider any action. Firstly, we may apply our reasoning to a too limited range of data; and secondly, we may allow some items to exercise an undue influence. The same is true of choosing our objectives; it is not simply a matter of weighing one against another, but of recognising that even for the most single-minded person no objective can exist in isolation. We live within a complex of common and conflicting purposes, and even the lifeless things with which we surround ourselves seem sometimes to have interests of their own. Engineers, it seems, are particularly subject to these alien influences, and it has become almost a commonplace among popular writers that in this modern world men are the creatures of machines. It is therefore pleasing to note that one famous British firm making automatic calculators design their 555 machines "to fit the job; not to have the job fit them."

It may be foolish to attribute motives to the inanimate, but so often the inanimate possesses an intrinsic logic which we follow to our cost. Tools and techniques have a logic of their own which, carried to extremes, defeats our very purposes in using them. Automatic data processing is a technique that enables us to plan and organise our business more successfully. But, the experts say, to apply ADP to best effect, an organisation must be adapted to meet the special requirements of ADP—possibly by an increase in centralised control. The technique is therefore seen to have independent interests, and it is only by recognising that an organisation has other aims than the efficient application of ADP that we may use the new technique to serve our ends rather than its own.

Science and engineering have become so hallowed in our age that, instead of bending them to our will, we tend to follow where they lead. They are thought to yield the greatest benefits in large countries with vast resources, so we seek to form ever more widespread political conglomerations. Why not instead use science and engineering to make even the smallest country prosperous? The same fault of applying logic in blinkers occurs in companies where all decisions are governed solely in terms of maximising profit. A company is after all a company of human beings, whose livelihood and happiness depend upon their work, each with his own objectives and ambitions.

By carrying some purpose to its logical conclusion, other, perhaps more important, purposes may be neglected. Performance is no doubt a virtue in a car, but an improved performance achieved by stripping out the seats may prove unpopular with the passengers. To take action in terms of a single paramount objective is like summing up a situation without reference to all the relevant information, or condemning a picture after viewing a small part of it through a microscope. The logic of a situation may seem entirely cut and dried until we look outside our normal field of vision. An expert billiards player knows that his cue is correctly aimed, that his ball will inevitably travel, first to strike his opponent's ball a glancing blow, and then irresistibly towards the red, driving it into a pocket and making a total score of five. Within the frame of the billiard table the future seems irrevocably determined. But unknown to the player, his wife is about to open the door immediately behind him, thereby confounding his stroke; or perhaps a jet aircraft, already out of control, is on the point of crashing through his roof.

But it is impossible to consider all the factors that have a bearing on our decisions, or all their consequences. The problem is to select those which may reasonably be allowed to affect our judgment, and only experience can tell us that. The philosopher Hegel—if memory serves its purpose—disdaining the piecemeal empiricism of scientific method, considered that nothing could be studied in isolation. Everything was linked in some way with its environment, and in turn the environment was linked to something else. Up to a point it was a very sensible attitude. Unfortunately, he appears to have carried his argument too far, maintaining that nothing could be profitably studied except in the context of the universe.

No doubt, every fragment of the universe is in some way affected by every other part, if only indirectly, by the tenuous linkages of gravity or the curious abstract fields of Einstein. Indeed, a man may raise his hand and disturb Arcturus. But experience shows clearly that fragments can sometimes usefully be studied separately. Perhaps Hegel was merely illustrating his own dictum: "What experience and history teach is this—that people and governments never have learned anything from history or acted on principles deduced from it"; for there could be no history at all if men had not studied parts of creation in isolation. Research workers might find themselves somewhat hampered if they adopted Hegel's view. There is something to be said for seeing one's data and even one's purposes in perspective.

Cover Picture:—*The electrometer-amplifier in a pH-measuring system is a detector of unbalance between potentials from the sensing element and the slide-wire potential of the recording instrument. Resistors and condensers are shown being connected into an electrometer circuit in the final assembly before testing and calibration.*

(*Nurnberg photograph for* ENGINEERING)

★ ★ ★

Plain Words

I would probably never have troubled to consider the Theory of Evolution by Natural Selection if the zoologists had not been celebrating the centenary of the historic paper by Darwin and Wallace. Now, I have suddenly realised that evolution also applies to engineering.

Look for a moment at the brief (by zoological standards) history of the motor-car. As soon as the species was originated, several varieties appeared. The petrol-engined design eventually came out on top, but the steam car had a brief innings and of course the battery vehicle is a variation which is still to be seen occasionally in suburban streets. Just as there are societies for preserving rare animals, so there are societies concerned with the preservation and continued use of rare machines.

When we think of evolution in engineering we have to adjust our time scales. A hundred years, to zoologists, is a tiny fraction of time; to engineers it is an era. On that basis the steam locomotive has lasted more than an era—a long life which may be attributed to " biological " fitness-for-purpose in the original designs and to the fact that locomotives have run on expensive tracks which have tended to perpetuate the species.

If engineering can learn from biological evolution it is that the process of natural selection should be allowed to operate without hindrance. Nature doesn't allow monopolies or restrictive practices. Nature could not work without standardisation; but within a general policy of standardisation, nature thrives on sufficient variety to ensure adaptation to changing conditions. In engineering this means that any conditions, such as political feather-bedding, which give artificial protection, will eventually be wasteful because they will perpetuate designs that are weak. For example, the standardisation of locomotives for British Railways, though it might produce designs which are efficient at the time they are introduced, would soon be stultifying. No one can see more than a few years ahead in the evolution of engineering designs; therefore there must always be some freedom, some competition, some natural selection.

The very latest practice in engineering is to cut out the prototype stage and go straight from the drawing board to production. (Nature has never fussed around with the clinical atmosphere of the laboratory.) This harsh requirement is an admirable discipline for designers, and I hope the philosophy behind it will long pervade our thinking as engineers.

CAPRICORN

Weekly Survey

British Engineering Looks at Europe

British industry has taken a lead in the promotion of trade in Western Europe by founding a permanent organisation to look after its interests. Under the expressive name " The Britain in Europe Committee " (incorporated as a company limited by guarantee) a group of leading figures from all sides of industry, finance and commerce have come together " to stimulate interest in Britain's participation in the proposed European Free Trade Area." The main function of the committee will be to undertake or sponsor original research on European economic integration and to make known its results. They will also provide specialised information and documentation besides initiating or supporting courses, lectures and meetings. Their basic objective, as stated in their terms of reference, is " to promote an understanding in industry in general of the issues likely to arise from British participation in the European Free Trade Area and to link this understanding with the initiatives in the political sphere necessary to secure ratification of the appropriate Treaty or Convention."

The chairman of the Britain in Europe Committee is Sir David Kelly. The chairman of the executive committee is Mr. Lawrence Robson, chairman of Associated British Engineering and the vice-chairman is Mr. Ernest Jones, the president of the National Union of Mineworkers. The engineering and metal industries' representation numbers 15 out of 32 representatives of manufacturing companies (the membership, including trade associations and trade unions, totals 56). It suggests that for many of the leaders in the industry the Free Trade Area is an opportunity they do not wish to miss.

Aircraft Exports Soar

During the first five months of 1958 the aircraft industry exported £64·5 million of complete aircraft and parts. This is 50 per cent more than the figure for the same period of 1957, representing an annual rate of export of £155 million compared with last year's record figure of £116·5 million. All categories of exports were up in the first five months of the year but pride of place goes to aircraft and parts which increased by 70 per cent compared with aero-engines at 33 per cent.

Over this period India has been the biggest customer followed by Canada, Western Germany, Iraq and Australia. Both Ireland and the Netherlands have been important customers as well. This recent export performance follows the geographical pattern in the last two years. India, for instance, has become a very important customer since 1956 and on the basis of 1957 and part of 1958 must rank as the most important customer in aircraft at the present time. The rest of the Commonwealth continues to be an important outlet. In western Europe the NATO powers are still important customers but there are signs that Sweden may be taking less than in recent years and the French aircraft industry has now developed far enough to be a serious challenger both in its domestic market and elsewhere in western Europe. Exports to the United States have varied a good deal from year to year, but it does not look as if they will achieve record figures in 1958 unless there are substantial deliveries in the last seven months.

The continuing success of British aircraft exports finds an echo in the annual report of the Air Registration Board for the year ended 31 March, 1958. In the report the board says that it has under consideration the necessity to issue certificates of airworthiness for exports of new aircraft sold to foreign operatives. Instead of issuing a normal United Kingdom certificate and associated flight manual, as has been done in the past, it is proposed to issue a certificate for airworthiness for export which will certify compliance with British civil airworthiness requirements plus such alternative requirements as are appropriate to the particular aircraft.

Rothes Colliery in Fife

After many years of increasingly intensive mining operations the coal reserves in some parts of the County of Fife in the Scottish Division of the National Coal Board are now approaching exhaustion, notably around the mining town of Cowdenbeath, but fortunately, there are large reserves awaiting development. New sinkings have been undertaken at Valleyfield, Seafield, Bowhill and Rothes, and extensive developments have been put in hand at the Michael and Wellesley Collieries, near Buckhaven.

Rothes Colliery, near Thornton, visited by H.M. The Queen and H.R.H. The Duke of Edinburgh on June 30, is the first of the new major sinkings projected for Fife to reach the initial production stage. The pit has been equipped with winding facilities and the surface layout, which is of strikingly modern design, forming a signal contrast to the conventional pit-head structure, is capable of handling a daily output of 5,000 tons of saleable coal. Two shafts have been sunk, each with a diameter of 24 ft and a depth of 2,928 ft, and both are concrete-line.

Production at present is between 400 and 450 tons a day and it is expected to rise to 1,150 tons a day in 1959. As underground development progresses the output will be steadily increased and, by 1960, Rothes Colliery should be employing 1,800 men, 1,000 more than at present, and producing 2,500 tons a day. By 1962, nearly 2,500 men will be required and the output should then be approaching 4,000 tons a day. The final stage of development should be completed by 1964, when the full complement of men will be in the region of 2,700.

The new coal mine will provide work for colliers from the older Fife mines where coal reserves are nearing exhaustion. The Rothes pit will operate a rich area of coal, some 10 square miles in extent, calculated to contain some 120,000,000 tons of coal. This is sufficient to assure the new colliery a life of about a century.

Iran and Iraq

The announcement at the end of last month that the Iraq Petroleum Company had restored the pre-Suez flow of oil to the Mediterranean following the destruction in November, 1956, of the pumping stations in Syria, coincided with the issue of three reports on development in the Middle East. The first of these, " Economic Development in the Middle East 1956-57 " issued by the United Nations Organisation, was intended to serve as one of the background documents for a general discussion of the world economic situation during the session of the UN Economic and Social Council which started on 1 July.

A review of economic developments in Iraq is given in *Iraq Oil in* 1957 published by Iraq Petroleum. The Iraq Government's revenue under the 1951 oil agreement has risen from ID 13·9 million in 1951 to ID 73·7 million in 1955. Of these amounts, 30 per cent goes into the National Budget and the remaining 70 per cent to the Iraq Development Board. Over the period 1955 to 1960, the planned use of oil revenues provides for an expenditure of ID 154 million on control of water, irrigation, drainage and agriculture, ID 67 million on industry, ID 64 million on roads and smaller amounts on railways, housing, bridges, public buildings, health and education, airports and ports. The

main industrial developments are naturally those based on oil and agricultural products. The former include a doubling of the capacity of the Baghdad refinery, a lubricating oil plant as an extension to the refinery and a bitumen refinery at Qaiyarah, south of Mosul. Other factories include a cotton textile plant opened at Mosul in March, 1957, cement factories at Sarchinar and near Mosul, and a sugar factory at Mosul.

In Iran the Development and Resources Corporation of New York, which is responsible under the Iranian Governments' Plan Organisation for a long-range development plan in south western Khuzistan on the lines of the Tennessee Valley Authority, has announced that the Italian chemical company, Montecatini, is to establish a plant at Ahwaz for the production of 9 million lb of polyvinyl chloride from natural gas. A nitrogen fertiliser plant is planned for Ahwaz using natural gas from the Ayha Jasi oilfield.

In both Iran and Iraq natural gas constitutes an important indigenous raw material and a number of proposals are being put forward for its exploitation. Ultimately, no doubt, considerable quantities will be required for the production of fertiliser for local use, but fertiliser consumption is at present very small in both countries and an extensive programme of agricultural experimentation is required before it can be developed. In the meantime, careful coordination of the various plans will be required if output is not to exceed the import requirements of neighbouring countries. Similar considerations apply to other products derived from natural gas and it is significant that Montecatini propose an expenditure of one to two million dollars on a two-year marketing programme in addition to the estimated six million dollars required for erection of the PVC plant.

Locomotive Building

The returns issued last week of locomotives scheduled for construction in 1958 are of particular interest from two points of view. In the first place, they show the rate at which diesel locomotives will become available under the Railway Modernisation Programme and in the second they provide an indication of the policy of the British Transport Commission as to the relative numbers to be built in the railway workshops and by the private locomotive builders. For a number of years the latter have argued that they should be allocated a substantial share of home orders for locomotives since by enabling them to spread their overhead charges, this would improve their competitive position in export markets. The 1958 figures show that while the railway workshops will continue to build the higher proportion of total requirements, the outside contractors have a substantial volume of work on hand for the B.T.C.

Out of a grand total of 553 locomotives of all types scheduled for construction in 1958, only 63 are steam locomotives and these will all be built in the railway workshops. The latter will also build six d.c. main-line electric locomotives of Southern Region type. Of the balance of 484 diesel electric, diesel hydraulic and diesel mechanical locomotives, 304 are scheduled for construction in the railway workshops and 180 by contractors. The total share of the contractors is of course, higher than is indicated by these figures because the railway workshops do not themselves produce power units for the locomotives which they assemble.

The building programme of the railway workshops is very largely concentrated on shunting locomotives of 200 to 350 b.h.p. comprising 278 shunting locomotives and 26 main line types of 1,160 h.p., 2,000 h.p. and 2,300 h.p. The contractors' programme on the other hand, includes 115 main line locomotives ranging from 800 h.p. to 2,000 h.p. and only 65 shunters of 200 h.p. to 300 h.p. The contractors will also supply the bulk of the diesel and diesel electric multiple unit railcars with a total of 707 against 463 from the railway workshops though this is offset by the fact that the railway workshops will supply 435 multiple unit electric coaches. If the 1958 schedules are realised, well over two-thirds of the 3,436 diesel and diesel electric vehicles so far authorised, will have been delivered by the end of the year, leaving only 939 for delivery in 1959.

EPU'S Vital Task

From 1 July the European Payments Union, the clearing house for payments on trade within Europe, was renewed for one year. This has been done each year since EPU was set up in 1950. But this year the discussions over continuing the arrangements have been more critical than usual. The main reason for this tension is the fact that the Common Market is due to make its first tariff and quota reductions in January. Whether this happens or not the relationship of EPU to the six Common Market countries raises important matters of principle.

Up to now trade within EPU has been on the basis of non-discrimination with members granting the same rights to each other. After 1 January 1959 the position will be different. A British exporter will have to pay 10 per cent more duty to sell his goods in Germany or Holland. The Swiss and Scandinavians will be in the same boat. Judged only on the Common Market issue of a break with non-discrimination there is reason to suppose that nothing very much will have happened by 30 June, 1959, to warrant abandoning EPU at this stage. But from the point of view of its adequacy to cope with the stresses and strains of the European payments position the situation is not so clear.

Persistently heavy French deficits and German surpluses have put a severe strain on the EPU machinery. If the extreme debit and credit swings which have been a feature of EPU are to be cured, something more constructive will be needed. One of the big mysteries in the discussions on the Common Market and Free Trade Area is how to prevent the new set up being dominated by Germany. Clearly the payments question is one of the keys.

Background to Expansion

The American recession is taking a long time to have an impact on this country's economic prospects. The latest trade figures show that the gold and dollar reserves in June went up by 37 million dol to put them at 3,076 million dol, the highest level since 1951. The rate of increase has fallen away owing to an early seasonal pressure on the pound but the fact remains that such figures denote strength rather than weakness. Meanwhile the impression is growing that this country is possibly faced with a decline in activity as part of a recession generated within western Europe. Certainly, an American looking at the trend of steel output and the stagnation in the official index of industrial production would say that a setback was starting from somewhere.

Such an idea seems to have been at the back of Mr. Heathcoat Amory's remarks in London last week when he referred to the hope that the Free Trade Area would provide a new long-term stimulus to expansion in western Europe to take the place of the rehabilitation boom which carried Europe forward in the first 10 years after the war. Furthermore there is no doubt that the countries producing primary products which are now feeling the full brunt of the effects of the American recession will need a blood transfusion in the way of increased capital investment to restore their prosperity and purchasing power and so absorb higher exports from the industrialised nations. The fact is that this country is fighting an economic battle on two fronts, in western Europe and in the countries producing primary products, many of which are within the Commonwealth. For the first time since the war an American recession cannot be offset by booming conditions in western Europe and the Commonwealth, notably Australia.

Letters to the Editor

EARNING A CAR IN AMERICA

SIR, I should like to congratulate ENGINEERING on having sent a senior member of its editorial staff first to Russia and then to the United States. His reports will help to give British engineers an insight into other peoples' ways of life; they may also help the British people to perceive some of the millstones which have been hung around the necks of British engineers by the governments they have helped to elect over the past thirteen years.

Mr. E. P. Ward mentions that he heard many complaints about the high prices of cars in America. I had the good fortune to spend six months out there recently, and I, too, heard this complaint from the lips of practically every other American I met: so I decided to investigate the facts there and then, and to see how the prices the American worker paid compared with those paid by his opposite number here at home.

It was, of course, important to realise that mass-produced American cars were much bigger and more powerful than mass-produced British cars, and that American wages were much higher than British wages. A reasonable basis of comparison appeared to be the number of hours an average hourly-paid worker would have to put in to earn the purchase price of 2,000 lb of motor-car in each country. The facts derived are shown in the accompanying Table; their sources were:—

British car dimensions and prices	*The Autocar*
American car dimensions and prices	*Automobile Industries*
British hourly earnings ..	*Ministry of Labour Gazette*
American hourly earnings	U.S. Department of Commerce *Survey of Current Business.*

The American prices were double-checked by direct approach (as a prospective customer) to Washington car dealers. I think someone must have been pulling Mr. Ward's leg about American car prices not including the coat of paint—or is he pulling your readers' legs? All the prices included in the Table refer to completely finished cars, without any of the optional extras—such as radio or heater—which were available in both countries at extra cost. The only material difference I noted was that in the United Kingdom the dealer was not allowed to sell below the list prices quoted. In America, the salesman had to work for his living, and I was offered a 300 dol cash discount off an 1,800 dol car, without even having to trade in a used car. I have not included this discount in the Table, as it would vary with current demand for the model of my choice.

The American car had a higher engine-capacity/tare-weight ratio than its British counterpart, and it was made from basic raw materials (pig iron and cold-rolled steel sheet) which cost more in America than they do here and using labour paid three times as much per hour worked: yet, despite the higher material and labour costs, and the extra value in the way of performance, its money cost to the purchaser before taxation was 16 per cent less per lb; after taxation, its money cost was 37 per cent less per lb. And its real cost after taxation (in terms of hours of work needed to earn the purchase price) was 79 per cent less per lb. These figures surely require no further comment, except, perhaps, to say that they reveal that the American worker's standard of living (where cars are concerned) was five times as large as ours, a ratio which is confirmed by the fact that in America, there was one car for every 3·2 people against one for every 14·1 people in this country. And some of our politicians blather about doubling our standard of living in the next 25 years: they must think we are a lot of tortoises beside the American hares!

When the average British worker can afford

Continuing Letters to the Editor

Some Comparisons of Typical 1956 *Mass-Produced British and American Cars (Six-cylinder, four-door saloons)*

Feature	United Kingdom Product		United States Product	
	Maker "A"	Maker " B "	Maker "C"	Maker " D "
Length overall	14 ft 4 in	14 ft 4 in	16 ft 6½ in	16 ft 5½ in
Width overall	5 ft 6½ in	5 ft 6½ in	6 ft 4 in	6 ft 1½ in
Plan area in sq. ft	80	80	104	101
Tare weight in lb	2,460	2,370	3,127	3,195
Piston-swept volume in litres	2·262	2·262	3·650	3·870
Swept volume per lb weight in cu. cm.	0·92	0·96	1·16	1·21
Basic price in February 1956	£532= 1,490 dol	£560= 1,570 dol	1,699 dol	1,675 dol
Price per sq. ft plan area	18·58 dol	19·68 dol	16·33 dol	16·60 dol
Price per lb weight (cents)	61	66	54	53
Price with 60 per cent purchase tax (U.K.); or with 10 per cent Federal tax and 2 per cent State sales tax (Washington, D.C., U.S.A.)	£799 7*s.* 0*d.* = 2,235 dol	£841 7*s.* 0*d.* = 2,360 dol	1,897 dol	1,872 dol
Tax-inflated price to purchaser (cents per lb)	91	100	61	59
Average hourly earnings of all hourly-rated workers in manufacturing industries (dol)	0·56		1·88	
Number of hours the average hourly-rated worker would have to work to earn the purchase price	4,000	4,220	1,010	995
Hours work required to earn the price of 2,000 lb of motor car	3,260	3,560	643	625

£1 = 2·80 dol

to buy a car himself, and can buy one without paying purchase tax to help to subsidise the free car the firm provides for his boss, we may, perhaps, begin to move towards the American standards of friendly relations between worker and management. Without such a move, we can never expect to attain America's productivity, for the workers' active co-operation will be withheld. This is not politics: it is just common sense.

Yours faithfully,
S. B. Bailey.

56 Blacketts Wood Drive,
Rickmansworth, Herts.
5 July, 1958.

ACCELERATED CURING TESTS ON CONCRETE

Sir, With reference to the letter from Professor J. W. H. King, published on p. 771 of your issue of 20 June, I would like to make some further comments on the question of accelerated curing tests.

Professor King somewhat takes me to task for what he considers to be a misuse of Road Note 4, because, he says, cements vary considerably in the strength gain from 7 to 28 days. This being the case, if the 28-day curve relating accelerated cured strength to normal cured strength is taken as a standard, it is not permisslble to publish a 7-day curve unless one makes some assumption as to the strength gain. I consider, however, that the 28-day and the 7-day curves are sufficiently close for normal or practical use, and it appears to me to be reasonable to make use of the relationship quoted in Road Note 4. Nevertheless, there is no real conflict between Professor King and myself, for we both agree that the constants A and B suggested by Ordman and Bondre in their modification of Plowman's maturity relationship are not applicable to this work.

Professor King goes on to say that it is clear that with the boiling-water technique one would *expect* different behaviour from different cements. I have made a search through the literature on the relationship of maturity to strength and I can find no evidence which would lead me to *expect* a difference. On the contrary, since boiling water at normal atmospheric pressure maintains a constant temperature, I would expect the results to be more consistent than those obtained with an electric oven.

We have found our boiling-water method to be easy to use for site work, and the apparatus required is simple. In view of the fact that our technique, at present, is to establish a curve for each site, it seems to me that there is little point in discussing variations in different curves that we have obtained; I consider our experimental results are not yet sufficient in number for a full analysis to be made. Professor King is correct in saying that I would not claim that our method of accelerated curing is not affected by variations in materials. It has always been my impression that any controlled form of heating would yield similar results, but if it now appears that one form of heating will yield constant results whereas another form of heating does not, then I think this itself is worthy of investigation, for it should throw some light on the mechanics of the curing of concrete.

Yours faithfully,
T. N. W. Akroyd,
Chief Engineer.

Constructional Services Limited,
123 Victoria Street, London, S.W.1.
1 July, 1958.

Plant and Equipment

CLEANING BAGASSE

Bagasse—the waste from the extraction of sugar from cane and consisting of fibre, pith, and dirt—is a suitable raw material for paper-making providing the fibre can be cleaned cheaply and separated from the pith. A modified swing hammer mill for the purpose which was developed by the Louisiana State University, has now completed a year of service in the Central Trinidad sugar mill. The resulting fibre is for use in the pulp and paper mill now under construction by Papelera Pulpa-Cuba S.A., nearby.

The Horkel depither was proved in the Audobon sugar factory and has been licensed for manufacture by the Parsons and Whittemore/Lyddon Organisation, 19 Saville Row, London, W.1. The two machines installed at Central Trinidad handled 250 tons of bagasse during the grinding season; the raw material is fed into the mill at one end and travels the length of the rotor across the top of the revolving hammers. The passage of the material is assisted by the hammer design which imparts a screw effect. The cleaned fibre passes out through a space in the housing at the end of the rotor and the pith falls to the perforated plate that forms the bottom of the housing. The action of the hammers tends to drive the pith through the holes in the plate. The machine can handle bagasse of varying moisture content, and enables much of the residual sugar to be recovered.

INSTITUTION OF HIGHWAY ENGINEERS

A new branch of the Institution of Highway Engineers was inaugurated at Carlisle on 19 June. It will be known as the Northern Branch and will cover the Institution's activities in the counties of Cumberland and Westmorland. Mr. D. Morris, A.M.I.C.E., county surveyor of Westmorland, was elected chairman, and Mr. A. N. Brant, B.Sc., A.M.I.C.E., an assistant county surveyor to the Cumberland County Council, was appointed honorary secretary. His address is Citadel Chambers, Citadel Row, Carlisle. The Institution, whose headquarters are at 47 Victoria Street, London, S.W.1, now has 11 branches.

INTERNATIONAL APPROACH TO GEARING

For some time past, increasing attention has been given by the Institution of Mechanical Engineers to the international aspects of engineering problems, and a number of conferences have been organised by the Institution to assist in clarifying world thought on such issues. Arrangements are now being made by the Institution for the holding of an international conference, at its headquarters in London, on gearing, which is expected to cover a much broader field than any previous conference on the same subject.

The whole meeting will be spread over a five-day week, from 22 to 26 September, with official visits to 15 factories and laboratories on the first and last days, and technical sessions in the mid-week period, from the Tuesday to the Thursday, inclusive. The technical sessions will be held on the mornings and afternoons of these three days and will comprise sessions on gear tooth loading; tooth forms, stresses and failures (two sessions); the production of large gearing; the production of medium gearing; measurement; and applications (two sessions). Some 40 papers will be presented and the international character of the conference will be strengthened by the number of these that will be contributed by authors from France, Germany, the Netherlands, Switzerland and the United States. Among the places to be visited will be the PAMETRADA research station, Wallsend; the Mechanical Engineering Research Laboratory, East Kilbride; and the laboratory of the Admiralty-Vickers Gearing Research Association, Barrow-in-Furness. The official language will be English.

Further information may be obtained from the secretary, Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, London, S.W.1.

SKIN-MILLING BY PUNCHED CARD

The most recent application of the E.M.I. electronic control system for machine tools is for a skin-milling machine built by the Cincinnati Milling Machine Company for the American aircraft industry. The basis system has only been slightly modified to fit this new application.

The machine has two 100 h.p. cutter heads which can be operated in unison or independently over the 30 ft by 8 ft work table. Tolerances as small as ± 0·002 in are well within the capabilities of the control equipment. Formerly the work was done using a copy tracing system involving a full size template; it is claimed that the electronic equipment is cheaper than the apparatus this involved. Four sets have so far been made at the Hayes, Middlesex, factory of E.M.I. Electronics Limited.

Continuing **Plant and Equipment**

COMPACT HEAVY-DUTY PNEUMATIC/HYDRAULIC RAM

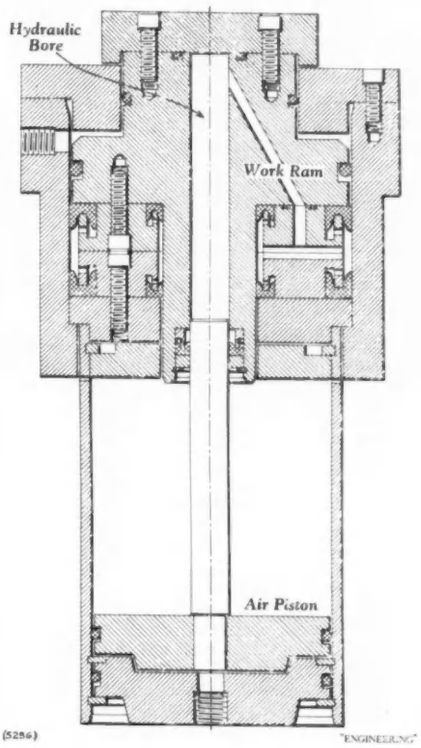
A pneumatic/hydraulic ram, known as the Polymation air ram, has been introduced by Polymation Limited, Lower Quay, Fareham, Hampshire. It is a self-contained air/hydraulic device which can be applied to operate industrial machinery in much the same way as a normal air cylinder, but has the advantage that with a moderate air-piston diameter and extremely compact dimensions, very high forces can be transmitted.

As shown in the accompanying illustration, the unit comprises an air cylinder, the piston rod of which serves as a small hydraulic ram operating in a bore in a work ram which is mounted in a pressure pot forming the closure for one end of the air cylinder. The work ram takes the form of a heavy piston with annular spaces above and below its larger diameter. The lower space contains an assembly of spacer rings and high-pressure U-packings to form a tight annular cavity which is connected by oil passages to the small central hydraulic bore. The upper annular cavity is also rendered pressure-tight by O-ring seals on the two diameters of the work ram.

To operate, air is applied to the underside of the air piston, which forces the hydraulic fluid in the small bore through oil passages to the inside of the annular U-packing assembly. This moves the work ram outwards according to the designed working stroke, and with a force which is multiplied by the ratio between the two effective hydraulic pressure areas. To retract the unit, air pressure is applied to the upper annular space, the effective area of which is sufficient (at negligible air consumption) to return the ram to its original position.

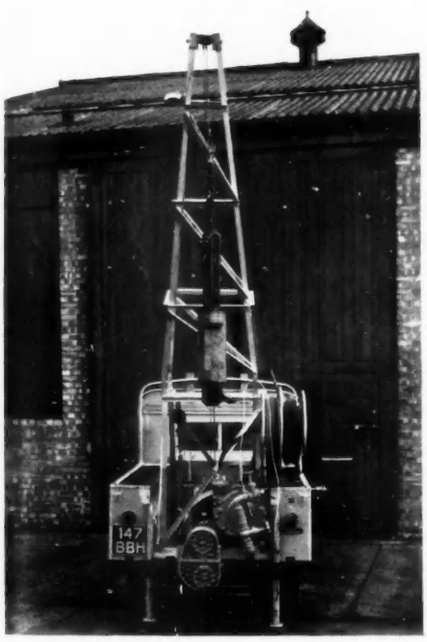
The ram illustrated has the following dimensions: overall height, 13·75 in; smaller spigot body diameter, 6·375 in; overall body diameter, 7·00 in; air bore, 4·50 in; air piston stroke, 4·50 in; working stroke, 0·10 in; working force, 20 tons; weight, 70 lb. Another version is similar in all respects except that the working force is 10 tons, and the working stroke is 0·20 in. The range is to be extended shortly to include loads from 5 to 30 tons, and working strokes up to 1 in.

Polymation air rams are designed to mount in a plain hole in the parent machinery. The bodies are machined to close limits for this purpose. They can often be used in multiples to double, treble or further multiply the force exerted. In such multiple installations where the forces required may vary from job to job, units can be cut out at will by the provision of suitable air controls to effect a direct and proportional saving in air consumed. Again, by the provision of appropriate volume and pressure regulating controls, the force can be regulated and applied slowly or swiftly as needed.



ALUMINIUM DERRICK FOR MOBILE PROSPECTING WORK

One of the features of a mechanical jet drill mounted on a Land Rover motor vehicle, designed and manufactured in this country for use in mineral prospecting by French geologists in West Africa, is a folding aluminium-alloy derrick. The rig is used to position a mechanical hammer which drives tubing into the ground in order to obtain sub-surface samples that are forced up out of the tube under the pressure of a water jet. The new drilling unit requires a crew of five persons only and is expected to bore between 180 and 240 ft a day in areas where drilling is unlikely to be conducted at depths greater than 30 ft. It has been designed by Dr. J. R. F. Joyce, built by Davenport Vernon and Company Limited, 31–34 High Street, High Wycombe, Buckinghamshire, and offers a quick and cheap method of drilling for most minerals.



An aluminium-alloy derrick mounted on a Land Rover motor vehicle for use with a mechanical jet drill in mineral prospecting in West Africa. The derrick is shown from the rear, extended in the vertical position, with the 250 lb cast-steel hammer block suspended from it by a cable.

The drive-head consists of a cast-steel block constituting the hammer and weighing 250 lb. This forms a loose-fitting sleeve about a $2\frac{5}{8}$ in diameter tube which is fitted with upper and lower stops to contain the block. The lower stop is a $5\frac{1}{2}$ in diameter pallet to which the drive pipe is screwed prior to the commencement of drilling. The hammer is attached by cable to an automatic winch connected to a rear power take-off drive through an electrically-operated clutch. The cable operates through a system of pulleys providing the necessary back tension to enable the winch to pick up the hammer and the latter to operate at various heights.

When the hammer falls, through a distance of 2 ft 6 in, it strikes the pallet at the lower end of the drive-head and causes a travel switch, attached to the top stop, to close. This completes an electrical circuit and so energises the clutch operating the winch, which then raises the hammer until it touches the switch, breaking the circuit, and making the hammer fall again. The rate of operation is designed to be 60 blows a minute, but by varying the speed of the engine a range of from 40 to 80 blows a minute may be obtained.

With a vehicle load over the normal maximum, weight saving was of prime importance and the use of Noral alloy B 51 SWP (a Duralumin-type alloy in the WP, or solution-treated and precipitation treated, condition) was stipulated for the derrick. The alloy was supplied by the Northern Aluminium Company Limited, which also assisted with the design of the structure, the weight of which is only 80 lb. The derrick is 14 ft high when extended, is constructed of $1\frac{1}{2}$ in by $\frac{3}{16}$ in angle material, and is fastened with anodised-alloy bolts secured with self-locking nuts.

When the vehicle is travelling, the upper portion of the derrick is folded over the cab and secured by an elastic rope to the spare-wheel mounting on the vehicle bonnet.

PORTABLE AMPLIFIER

A portable transistorised amplifier, which weighs 5·5 lb, is being manufactured by Pye Telecommunications Limited, Cambridge. It is the type PTC 1010 and has an output of 10 watts. A 12V, 1·8 A power supply is required. The unit is suitable for amplification of speech and music, and measures 8 in by 3·5 in by 6 in. A selection of microphones and loudspeakers for use with this amplifier is available.

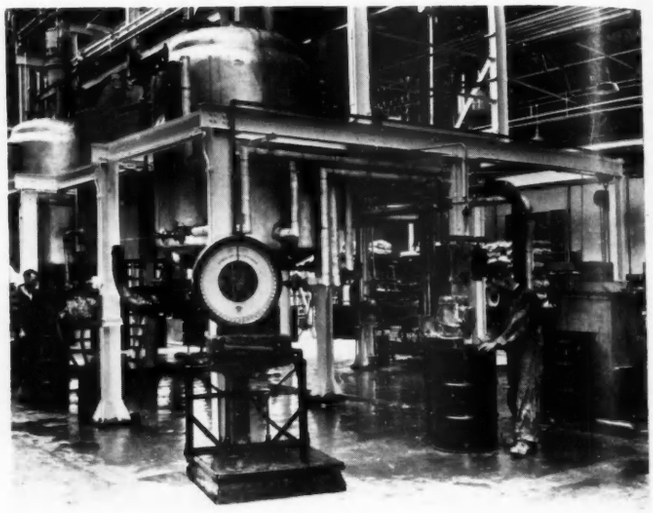
(Right) Transistorised amplifier for speech and music weighing 5·5 lb.

Metals and Materials

DUNLOP RUBBER COMPOUNDING FACTORY

In their recently-built factory in Birmingham, the Compositions Division of the Dunlop Rubber Company Limited, are now producing latex compounds and adhesives in new plant specially designed by their own chemical engineers for this purpose. A special feature of the plant is the large mixing and vulcanising tanks which provide for the mixing of products at low or high viscosities, the vulcanising of compounds at a range of temperatures, and the de-aerating of mixes under controlled conditions, when required. Two obvious advantages arise from this. In the first place, the precise control of the temperature ensures uniform vulcanisation, thereby giving a more satisfactory product. Secondly, reduced handling improves labour efficiency and minimises waste.

The principal applications for the latex adhesives produced lie in the fields of carpet seaming and carton and package sealing. Vulcanising latex compounds are mainly used for carpet backing, while the pre-vulcanised compounds produced are employed in the manufacture of toys, gloves and teats.



A portion of the latex compounding plant, containing two 500-gallon vessels for the preparation of pre-vulcanised latex, in the new Dunlop factory at Birmingham.

"SAROY" TOUGHENED PLASTICS SHEET: FILM

A proprietary thermo-plastic sheet material, which on account of its good fabrication qualities, high impact resistance and other useful physical and chemical properties is finding many useful applications, is "Saroy," a product made by Saro Laminated Wood Products Limited, East Cowes, Isle of Wight. A new film on "Saroy" has recently been issued.

With the aid of vacuum forming techniques, deep drawn components of many sizes can be produced, typical examples being trays and liners of refrigerator cabinets and other components such as photographic and catering trays, television masks, advertising signs and displays, as well as toys and novelties. Some of the physical properties of Saroy are given in Table I.

TABLE.—*Some Physical Properties of Saroy (Styron 475) Sheet*

Tensile strength, lb per sq. in	3,200–4,000
Elongation, per cent	10–20
Modulus in tension, 10^5 lb per sq. in	3·3–3·8
Impact strength (Izod), ft lb per in of notch	0·8–1·2
Coefficient of thermal expansion, in per in per °F 10^5	4·0–4·5
Specific heat, cal per g per °C	0·3
Specific gravity	1·05–1·07
Dielectric constant, 10^6 cycles	2·5–2·6
Water absorption, per cent 24 h	0·12

The raw material for Saroy sheet is polystyrene (Styron 475), which is manufactured by Distrene Limited. Pigments are added to enable sheet to be made in a range of standard colours such as green, white, red, gold, blue, etc. Pellets of this material are fed into extrusion machines which are capable of extruding sheet of thickness ranging from 20 to 250 thousandths of an inch, and up to 48 in wide and 100 in long. As extruded and rolled, the sheet has a matt finish but a high gloss finish can be obtained by rolling on to the surface a laminate of thin polystyrene film.

Another laminated sheet product, Saroy P.F., is surfaced with paint in a variety of designs and colours which are protected and given a high gloss by an overlay of clear polystyrene film; this type of sheet, which has many decorative applications, can be formed and worked in the same way as Saroy sheet.

The sheet, uniformly softened by electrical heaters, is easily formed on suitably shaped moulds by one of the vacuum forming methods. Special machines have been designed for automatic continuous production of components from sheet fed to the machine. The 30-30 drape and vacuum forming machine (Messrs. T. H. and J. Daniels, Stroud) is an example. Plug-assisted and "Airslip" forming methods may also be applied. The latter process is used on the "Formvac" machine (Hydro-Chemie Limited, Zürich). One of these machines will produce continuously vacuum-formed containers and closures: sheet from a roll is fed into this vacuum-forming machine where it is clamped, heated, formed, cooled, stripped from the multiple unit mould, and conveyed to the shearing station where the articles are automatically trimmed. A photo-cell device accurately locates the sheet (maximum area 24 in by 36 in) over the mould. Using 0·020 in thick sheet 40 half-pound ice-cream or margarine tubs can be formed simultaneously, giving a production rate of 4,000 containers per hour. With the Formvac, U.5 machine refrigerator components, 40 in by 60 in, and 24 in deep, can be formed.

Saroy sheet can be machined with standard woodcutting equipment, drilled, guillotined and blanked. By selecting suitable adhesives it may be bonded to plastics, cloth, glass, metal, paper and wood; joints can also be made by welding techniques. The sheet surface may be colour-printed by roller coating, selective spray coating, silk screen and lithographic printing processes.

The new film, "Saroy," was recently released by Saro Laminated Wood Products Limited and British Resin Products Limited. It shows the method of manufacture, stringent tests to control quality during production and the automatic production of deep-drawn components. Technical enquiries should be addressed to the Technical Service Laboratories of the producers.

BRIGHT SILVER ELECTROPLATE

For many domestic and industrial applications bright silver electroplated deposits are desirable and Engelhard Industries Limited, Baker Platinum Division, 52 High Holborn, London, W.C.1, have now introduced a plating process to accomplish this. The normal electrolyte contains, in troy oz per gallon, fine silver 5·3, potassium cyanide 14·4, and potassium carbonate 2·4, and its pH value is approximately 12·3. What are termed special "brighteners" are added to the bath, which is used at room temperature and possesses excellent "throwing power."

It is stated that a mirror-bright finish is obtained on articles over a complete range from a flash coating to a heavy deposit and that these are hard (Vickers P.N. 135) and highly ductile. Uniformly good results are obtained using current densities ranging from 10 to 40 amperes per sq. ft and the clear transparent solution enables the plater to watch the work in the process of being plated.

Other advantages claimed for the process are non-critical economical operation and control, and the fact that organic contamination can be removed by filtration through activated carbon.

FOR HOT ELECTRONICS

A miniature electron tube, said to be constructed of layers of titanium and ceramic, capable of operation at temperatures between 500° and 800° C is under development at the research laboratory of the General Electric Company, U.S.A. experimental models are flat discs of 0·24 in diameter and 0·125 in thickness. Their extremely small size is largely due to the fact that they have no heater—the heat required is provided by the environment.

BRITISH STANDARD FOR GALVANISED STEEL SHEET

Prepared at the request of sheet makers, a new British Standard, designated B.S. 2989: 1958, concerns galvanised steel sheet coated by the continuously hot-dipped galvanising process, from coil produced on a wide-strip mill. Six classes of plain steel sheet and coil, thinner than 0·118 in (3 mm) and having a maximum width of 48 in (1,220 mm) are dealt with.

The six classes are divided into two groups. For group 1, comprising classes A, B and C, the stipulated weights of zinc coating range from 2·5 oz per sq. ft to 1·5 oz per sq. ft. For Group 2, consisting of classes D, E and F, the zinc coating is lighter, but the products have additional fabricating properties.

Steel sheet and coil in the first group are subject to a test for coating adherence only. This group is intended to provide a high degree of protection against corrosion. In general, the product will be used in the form of flat sheets, although it can be bent to a limited extent.

The first class (D) in the second group, which usually possesses a zinc coating of from 1·1 oz to under 1·5 oz per sq. ft., is intended for general use, but not for severe bending or forming. The remaining two classes in this second group (E and F) provide for severe bending.

Dimensional tolerances on sheet and coil and also detailed tests for the determination of the weight and adherence of the coatings are laid down in the new specification, copies of which, price 3*s.* 6*d.* net, are obtainable from the Institution, 2 Park Street, London, W.1.

Companies in the News

Reinforcing the Big Battalions

The Finance Corporation for Industry has announced a loss of £902,322 in the year ended 31 March, 1958, compared with a profit of almost £53,000 in the year before. This has been brought about by the need to write off £1·2 million in its investments. This was a rather grim statement for the new chairman Lord Weeks to have to make as his first pronouncement from the chair.

The FCI, in contrast to the Industrial and Commercial Finance Corporation, is concerned with financing larger industrial ventures where other financial institutions and the capital market in general would hesitate. The risks it must take are always therefore considerable for they must be hazards which the ordinary investor hesitates to act upon and they must be big risks in terms of money or they would go to ICFC. At the present time a very high proportion of FCI's investments, about half, is in iron and steel. This is a political risk where the chances of FCI not making at least a modest profit are small. Nevertheless the fact that FCI has to carry a political risk, which the investor will not assume, ties down its resources and limits the range of investments which it can carry. This limitation is superimposed on the one which already exists, namely, that its risks must be big ones at any time to fulfil its terms of reference. As long, therefore, as the threat of nationalisation hangs over the steel industry the FCI is in a particularly unenviable position. Meanwhile the Corporation has been able to replace some old loans at low rates of interest by new ones at high rates and this has helped it to increase its gross revenue. One of the main means it has of defending its profitability at the present time is the skill which it can deploy in accepting loans at what are to itself attractive rates of interest.

Expanding Telecommunications

The demand for telephones is growing throughout the world at a rapidly increasing rate. Last year the overall increase was 7·6 per cent (in the United Kingdom 4·9 per cent) and there is new evidence that telecommunications are playing an increasingly vital role in the economic development of many countries. The United Nations Technical Assistance Board have obtained very comprehensive information on this subject through the International Telecommunication Union (ITU), who are giving technical assistance to under-developed countries. The demand for the products of the telecommunications equipment industry should therefore continue to grow. The main difficulty, which appears to be world-wide, is the shortage of capital to finance major schemes. Sir Thomas Eades, chairman of Automatic Telephone and Electric Company Limited (ATE), emphasised this in his annual report, saying that "the demand exists, but assistance in connection with the finance is increasingly important."

At home in particular, credit restriction and heavy cuts in the Post Office Estimates for 1958-59 are expected to have "serious effects on the ordered development of the telephone service." This point was made in the annual report of the Telecommunication Engineering and Manufacturing Association which also contains a review of the progress of telephonic communication in most countries outside the Soviet Bloc, China and India. The statistics are taken from *The World's Telephones*, published by the American Telephone and Telegraph Company. They show the number of telephones in each country having over a million, the number per hundred of the population, the proportion of telephones working to automatic systems and the number of conversations per annum per head of the population. The United Kingdom is lowly placed in all but one of these categories—the total number of telephones installed, which totalled 7·2 million at 1 January, 1957, represented a 4·9 per cent increase during 1956. Over half the world's telephones, 60 million out of 110 million, were in the United States, which also had the highest proportion per 100 population—35·45 compared with 31·5 in Sweden, 27·56 in Canada, 25·50 in Switzerland, 18·48 in Australia, with Hawaii, New Zealand, Denmark and six others all coming before the United Kingdom's 14·04.

TEMA's review of Post Office business is highly critical of changes in the Government's policy, considered wasteful of effort and money.

Hunslet's Issue

A debenture issue of £300,000 (6½ per cent debenture stock 1978/83) is being offered by Hunslet (Holdings) Limited which became a public company last month. But Hunslet's history goes back a very long way, to 1837 when Matthew Murray started building locomotives in Hunslet. The Hunslet Engine Company Limited was formed in 1864 and incorporated in 1902. They pioneered the introduction of diesel-engined locomotives (in the early 1930's) and have developed a wide range of mining and shunting locomotives which have sold in substantial numbers in most overseas markets. At home a new design of 200 h.p. shunter has been accepted by British Railways and orders placed under the modernisation programme. The profit record since the war is better than that of most other companies in the industry. Prospects are considered to be reasonably good and full capacity production is assured for 18 months.

In recent years the company have developed in other fields though three subsidiary companies, Hattersley Pickard and Company Limited, which make automatic hydraulic machinery for the textile trades, Scootacars Limited, which have this year begun production of a three-wheeled car, and Hunslet Precision Engineering Limited, which were formed this year "to develop the design and sale of specialised hospital and university equipment, especially equipment connected with radioactive gamma-ray isotopes."

The additional capital is doubtless earmarked to finance the company's diversification and, presumably, further growth.

Merger in Office Machines

The announcement last week that "agreement in principle" had been reached for a merger between British Tabulating Machine Company and Powers-Samas Accounting Machines, took the office machinery industry by surprise. Vickers, with whom Powers-Samas are associated, have agreed to the deal—subject to the consent of all other parties concerned—and it is fairly certain to go through. A new operating company will be formed, British Tabulating receiving 62 per cent of the shares and Powers-Samas 38 per cent. The two companies' chairmen, Sir Cecil Weir and Mr. A. Terence Maxwell, warn that the full details will take time to prepare, probably until early next year.

The merger is taking place at a time of prosperity in the office machinery industry. British Tabulating reported a group profit of £1·2 million in 1957 and Powers-Samas a "record number of deliveries." The industry's turnover rose by £10 million, to £75 million and exports have increased substantially. The merger brings together two of the five leading makers of punched card machinery and computers. Research and development, so vital in this field where technical change is probably more rapid than in any other, will benefit from greater financial strength and co-ordinated effort. Their principal competitors, International Business Machines (the largest in the world but relatively small so far in Britain), Remington Rand and Burroughs, all United States controlled companies, and another, National Cash Register, operate in association with Elliott Automation, which have strong American links through the Bendix Corporation.

The new company will be in an excellent position to lead the British industry in fields which have so far been a practical monopoly of the United States.

Fifty Years of Aircraft

The aircraft industry is still thought of as a young industry. Many of the companies whose names are household words of the present day can trace their history back to the pioneers of the 1900's, and a handful of the pioneers themselves still remain. Vickers, who later this month celebrate the fiftieth anniversary of their aviation interests, had perhaps a more solidly backed initiation than most. Their first venture, the airship known with a hint of irony as the "Mayfly" was backed not only by the board of Vickers Sons and Maxim Limited, but also, to the extent of £35,000, by the Admiralty. This machine, though not successful itself, was the forerunner of a considerable number of airships.

Vickers started building aeroplanes in 1911, one of the earliest machines being the first gun-carrying fighter, the FB1, which was developed into the FB5 "Gun Bus," in service on the Western Front in 1914 and 1915. The later Vickers Vimy has a place in history as the first aircraft to fly the Atlantic non-stop.

Among the many aircraft designed by the company since then, a few stand out as spectacular successes. Perhaps the earliest is the Supermarine S6B which won the Schneider Trophy outright and set the world air speed record at 407 m.p.h. as long as 27 years ago. Following this the Spitfire of World War II and the Wellington bomber were produced in very large numbers.

Up to the end of the last war, Vickers was largely based on military aircraft. Since then, however, following the success of the Viscount—unprecedented for a British aircraft—the company have steadily increased their civil interests, until at the present time their future lies predominantly in the construction of large aircraft for the world's airlines.

Platt Brothers Flourish

Platt Brothers (Holdings) have staged a very good recovery during the last year. Net trading profits after depreciation were up from £1·18 million to £1·93 million and Mr. K. H. Preston, chairman of the Group, expressed his confidence that there would be no fall in turnover during the current year. There has been a considerable improvement in the intake of export orders for textile machinery and this has more than made up for the disappointing home trade.

The Platt Group is extending rapidly into other fields of engineering. During the past year they acquired Le Grand, Sutcliff and Gell, who are leading makers of oilfield equipment, and Hayward Tyler, whose sales of pumps to the oil industry (both process and cargo pumps) are greater than those of any other maker. This gives the group a major stake in the growth of oil and Mr. Preston anticipates that the present curtailment of purchases will not continue for very long. Towards the end of last year, the group acquired Epsylon Industries Limited, designers and manufacturers of electronic equipment (mainly magnetic recording devices), and intend to develop and expand this company's business.

Platt Brothers have been equally active in their search for new products for their existing companies and in the re-equipment of their factories. Platt's Hartford works in Oldham has been rebuilt at the cost of nearly £1 million, and considerable gains in productivity are expected from the use of the most modern facilities. Dobson and Barlow have successfully established themselves as manufacturers of machinery for the brewery and soft drinks industry; (by means of an association with Barry, Wehmiller Machinery Company of St. Louis-Missouri, who are one of the makers of this type of equipment in the United States).

Talking to Americans

AMERICA IS STILL GOING PLACES

Concluding his series on the American scene, Mr. E. P. Ward seeks to interpret his impressions, under the heading Beyond the Frontiers. In previous articles he has presented a survey of current American thinking; now he considers where it leads. A first introductory article entitled I Like Americans (6 June) told where he went and whom he met; the second, The Territories (13 June), began a group of articles under the general heading America is Still Going Places and gave a brief picture of American life followed by a consideration of the business recession. The Trails (20 June) discussed certain vectors in the pattern of American growth. The last two issues of ENGINEERING (27 June and 4 July) included reports on The Frontiers, in Management, Education and Research. Mr. E. P. Ward, who is a deputy editor of ENGINEERING, has recently toured the United States after a visit last year to the Soviet Union.

BEYOND THE FRONTIERS

WHEN in a momentary burst of confidence, I wrote: "Only an Englishman would be so arrogant as to believe that he could see the future of a great and varied nation like the United States after a short visit," I presumably supposed I could. Well, this Englishman is now having second thoughts. Maybe I should have taken the advice sometimes seen on pasteboard cards placed in the vicinity of telephones: "Plug in brain before starting mouth"; for, although first impressions are sometimes valuable, the experiences of a first brief visit are hardly adequate excuse for laying down the law. Nevertheless the Englishman's arrogance is irrepressible; so here goes.

CENTRAL DILEMMA

As I see it, the central dilemma of the United States is one of objective. America has a choice, in that it may continue to be administered solely in the interests of its people as individuals; or it may seek to establish and maintain its competitive position as a nation and as a leader of nations. These aims, though overlapping and indeed interdependent to a great extent, are not identical, and call inevitably for different measures. The problem will be to reconcile the two, or rather to determine the degree to which each should influence the nation's policy. Put in material terms, America has to decide how much present comfort and convenience it is prepared to sacrifice in order to secure its future leadership, what proportion of current expenditure is to be allocated to capital and educational investment.

Mr. George F. Kennan has suggested that the challenge uttered by the Soviet Union is an invitation to a contest which can have little meaning for America, with goals and rules drawn up by the challenger. But America cannot fail to answer even so artificial a challenge; for its own security depends on the conviction of friendly and uncommitted nations that the American way of life delivers the goods. That being so, America may seek to subsidise potential allies—a policy that after a certain stage becomes abortive—or continue to enrich its own people and those of like-thinking countries by its traditional process of individual enterprise, in the belief that backward countries may wish to take the same road to prosperity, demonstrating their allegiance by imitation. In the words of Mr. Henry R. Luce, "Abundance is not achieved by doles or handouts but by wealth-creating activities."

In taking this second course America may appear to ignore the challenge, since no dramatic change in its philosophy would seem to be required. However, even to be conscious of a contest is to be affected, though in ways that may not be immediately apparent. One readjustment that is likely to follow from this situation concerns the utilisation of resources. Supplementary factors pointing in the same direction are the growth of United States and world population, and the present size and influence of American public and private institutions, leading to a certain overlapping and interlocking of function. When resources far exceeded the national capacity to use them, the production of wealth could proceed in a prolific and haphazard fashion, much as the forests were consumed early in the present century. In present conditions America will be less concerned to maximise its current wealth than to secure maximum long-term utilisation of its resources.

It follows that there will be increased correlation of activity. There is already a growing belief that the greater the range of resources that a single authority controls, the more efficiently can these resources be put to use; from different points of view both the Development and Resources Corporation and Arthur D. Little Incorporated operate on the basis of this assumption. Dean Harrison of MIT has also pointed out that Government supervision is increasing to some extent. But in the American context this approach to rationalisation is likely to be only partly effective, and even the Soviet Union appears to have found total centralisation unmanageable. There is also the problem of retaining that useful reflection of economic reality, the price system. How then can the necessary integrated utilisation of resources be achieved?

INSTRUMENT OF SOCIAL LEADERSHIP

In the United States, the corporation occupies a special and unassailable position in the economy. It exercises considerable influence and has evolved into an extremely efficient and usually enlightened unit of society. Adolf A. Berle Jr. has suggested that it is emerging as an instrument of social leadership. What is more, in spite of the high degree of discipline it exacts, it still leaves the individual substantial freedom of choice, and, unlike the corporate state, allows its employees to escape into another administrative environment when the day's work is done. Nevertheless, it is large enough to control a wide range of resources, and its growth might well be redirected to meet the new conditions.

Such a readjustment may require a fresh outlook on monopoly. Indeed, the climate in which the anti-trust laws were formulated hardly exists to-day. With the growth of employee shareholding and participation, producer and consumer increasingly share the same pair of shoes; and competition between different products for the consumer's income may regulate prices as effectively as competition between similar products. Occurrence of a business recession suggests that greater flexibility for diversification by association and for changeover to new products would be desirable. Wage agreements, the remoteness and distribution of

Crystal growth and interlocking function. Central Park seen from Radio City.

What They Are Thinking and Where it Leads

shareholders, and the organisational difficulties in changing prices at short notice have made response to market pressures sluggish. It is perhaps for these reasons that a contributor to the *Harvard Business Review* calls for "a new kind of theory in which the unseen hand of Adam Smith will be replaced by the visible hand of business bureaucracy"; while Dean Harrison emphasises America's "need for new types of administrators." Consistent with this more bureaucratic approach is the current tendency to tie technology increasingly to economics.

The mechanism for an expanded corporate bureaucracy is likely to be complex, but automatic data processing and the considered application of decentralised control will help to make it workable. There will no doubt continue to be a need for small organisations with minimum overheads, and means of making such concerns financially profitable, especially when they are necessarily of a transitory nature, might usefully be devised. Attention might also be given to the detailed study of economic manufacture in small and medium batches, and to the problem of changeover from expanding to replacement production, or to entirely new products, when market saturation occurs. But whatever changes may take place, complexity is likely to increase, and, without proper care, the discipline a complex society impose on the individual may become insufferable: social pressure on personal liberty can sometimes be as onerous as authoritarian control.

ONE PARAMETER LESS

What therefore is likely to be the future relationship between the corporation and its employees? Mr. John S. Crout, of Battelle, has observed that "We are entering an age when management, without paternalism, must accept a greater responsibility for the total livelihood of all employees." The corporation, with its salaried managers and distributed ownership, has frequently shown considerable common feeling with its employees, exhibiting in the words of Mr. John Dos Passos "the knack of insinuating under the scaly armour of self-interest all sorts of distracting independent notions." Job extension and employee shareholding are examples. Thus to commit the loyalty of an employee by inviting him to purchase shares likewise morally commits the company to an increased responsibility for the employee.

It follows that the parameters available to managers for coping with economic and market fluctuations may in future not include the laying off of men. Indeed one American spoke warmly of a pre-war German edict by which firms were obliged to take a due proportion of the labour unemployed at any time. Clearly, if the elimination of this degree of freedom is to be possible (and the guaranteed annual wage is a step in this direction), corporations must have a wide spread of manufacturing interests so that labour made redundant by a slackening in demand for one product may be translated to another. This raises the question of trade union jurisdiction and demarcation, problems that must be settled before any complete rationalisation of industry can be undertaken.

Eventually, if participation proves workable and is used to promote a real community of interest and not simply as a tool of management, the trade union may prove unnecessary in its present form and disappear, like the human tail, though some means of defending the individual against exploitation by the group will continue to be required. It may be recognition of this trend that has prompted Mr. Walter Reuther to secure a guaranteed wage for his union and to propose a profit-sharing scheme. He appears to be preparing the way for a new concept of trade unionism, and it is not surprising that he has been accused of usurping the functions of management. Such a development would not eliminate the profit system, but merely involve employees more deeply in the organisations for which they work. Thus, Henry Ford II has blamed the recession on the unions: high wages have caused high prices and thereby diminished sales; if joint industrial responsibility comes about, employees may see their interests identified with the company's.

If the corporation is to be the key unit of the economy, how does it fit into the national structure as a whole? Perhaps its place can be more readily appreciated if the state is regarded as a highly decentralised organisation with the corporation as an autonomous division. The corporation's pre-eminence is justified in that responsibility for decision is placed not primarily at the centre but at the point where the significant action occurs, where the relevant information is most readily available, and where the consequences are most likely to be felt. The corporation is thus the middle level in society where organisation is detailed and comprehensive, consequently where discipline is most apparent. Overall policy is formulated by Government, which, like the president of a decentralised company, has its nation (company)-wide services—treasury, accounting, legal, research and other staff.

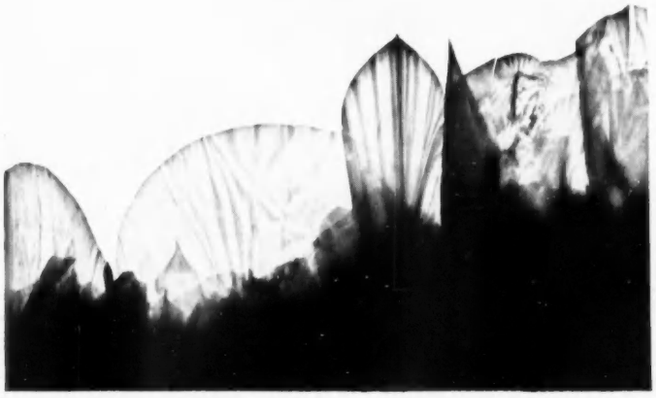
At present there is no such formal relationship between Government and business; business is rather an estate of the realm, a product of that division of powers that is so fundamental to the American constitution and way of life. Not only is "get the Government out of business" a popular rallying cry, but I have also heard the demand to "get business out of Government." The division between Government and business has, I understand, created problems during negotiations on military production between the United States and Britain, where the Ministry and industry work more closely together.

Companies are at pains to avoid dependence on the Government, and even in the field of nuclear energy, which is not yet a competitive source of electric power in America where conventional fuels are cheap, the utilities do not want the Government "to carry the ball." Dr. Paul Genachte, of the Chase Manhattan Bank, explained to me how companies were able to justify economically the construction of large nuclear power stations. It would appear that unwillingness to invest private money in uneconomic projects, or projects from which returns could be expected only after 10 or 20 years, would tend to hamper long-term development in communities where corporations were the fountainhead of economic power. This is fortunately not the case, at least in the field of nuclear energy.

FARSIGHTED PRIVATE MONEY

Some 75 per cent of installed electrical capacity in the United States is privately owned and many private utilities are very large; Consolidated Edison, for example, controls more than 4 million kW. Thus even 200 MW of nuclear capacity (about 5 per cent) would not affect significantly the overall cost of power before transmission. But the nuclear plant and fixed charges represent only a small part of the total cost to consumers including transmission, so the effect of the slightly more expensive nuclear power would be immensely diluted, amounting to a fraction of 1 per cent—a figure that cannot be taken into account in operations of this kind. Thus although they are not competitive, nuclear power stations may still be profitable and the negligible diminution in profit involved in building them will be amply recompensed by the experience gained. In any case, present philosophy appears to entail a Government subsidy for the research and development phase of reactor engineering.

However great the attempt to achieve a complete separation of powers, there can be no doubt that Government and business are interdependent: military contracts are of considerable importance to many American firms; Government research and development organisations such as the Atomic Energy Commission can alone command the resources to carry out superscale basic research, which must precede commercial exploitation of the results; and indeed, the laws corresponding to our limited liability and company acts are the very foundations on which business is established. In the future, it



Crystal growth and private research. Fine sheets of crystals (12×10^{-5} *in high*) *erupting from the surface of stainless steel are believed by Westinghouse research workers to explain the phenomenon of stress-corrosion cracking.*

Memory and complexity. A disc memory (left) enables the IBM Ramac 305 computer to record and process vast quantities of information. Only by automatic data processing can the requirements of modern society be met.

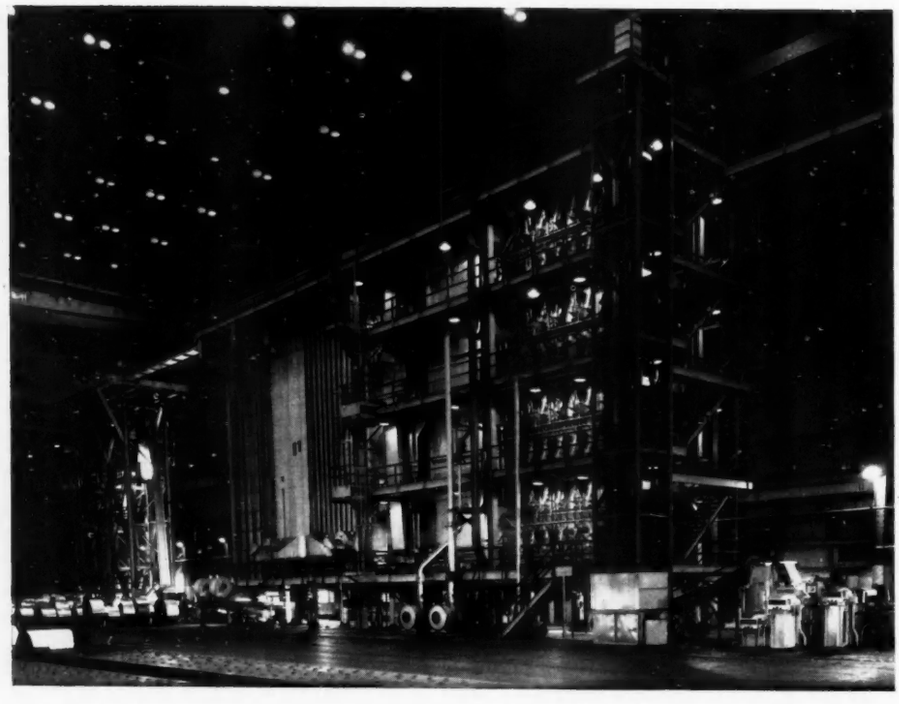
Talking To Americans

seems likely that each will extend its influence further into the other's territory, thereby strengthening the relationship. Government has already, in some cases rather furtively, undertaken projects that have in the past been essentially the province of business; and companies have evolved their own schemes of assistance for underdeveloped countries, a duty that was hitherto confined to Government.

THREAT

It is more difficult to determine America's future relationship with the Soviet Union. At best, we can hope for a stalemate until tempers and political philosophies have cooled, and meanwhile try and see the situation in perspective. No doubt it is true the Soviet Union has outstripped America in training engineers; but how has this been done unless the training has been basically in the use of handbooks with large classes and little individual tuition? If that is so, Russian engineers will be skilled in applying existing techniques, but less able to develop new ones. This need only be a temporary weakness but it provides at least a breathing space I also concluded following my visit to the USSR that as the numbers of engineers increased, there seemed to be diminishing returns in making proper use of them.

But it would be foolish to feel complacent. Dean Harrison has suggested that America may well be overtaken within the next 15 years, and Mr. Allen W. Dulles, pointing to the extraordinary rate of growth exhibited by the Soviet gross national product (now more than 40 per cent of America's and increasing at nearly twice the rate), has warned: " Certainly here we have the most serious challenge this country has ever faced in time of peace." (The Soviet population



Steel and private resources. Large companies can alone afford the massive capital investment required for such installations as this United States Steel Corporation tinplate plant.

is roughly 200 million as against 168 million in the United States.) American education has widely degenerated into " personal grooming " and, according to Dean Harrison, is " rotting at the roots right now." He also declares that America is " greatly handicapped by secrecy, because many of the people who would have the best ideas about the subject don't know what is being done." Presumably in a totalitarian country, where the frontiers are impenetrable iron curtains, internal scientific and technical intercourse can be unrestricted.

American research, with its diverse and flexible institutions, has many advantages over the more rigid Soviet approach, but here, too, Americans have proved themselves willing to learn. Dr. James R. Killian, Jr., has observed: " We need to find new institutional patterns and relationships to provide research facilities adequate to deal with modern research techniques but too expensive to be confined to a single institution. We must develop the counterparts of the research institutes in Germany and the USSR, but we must do it by properly relating them to our universities, and thus avoid a serious weakness in the foreign institutes."

HOT DOGS AND EVOLUTION

An American advantage to which a writer in the *Harvard Business Review* has drawn attention is in the understanding of people through the social sciences. Another is the existence of an informed public. *The New York Times* has published an excellent little booklet *Get More Out of Your Newspaper*, which is a concise guide to newspaper reading. It divides newspaper content into five categories: current information (" More than three billion hot dogs were consumed by the American people last year."); interpretation (" The popularity of the hot dog makes it virtually a national institution."); opinion (" The hot dog is delicious."); argument (" Since hot dogs are an excellent source of protein and their manufacture gives employment to thousands of persons, everybody should eat at least one hot dog a day."); and special pleading (" Eat Zilch's hot dogs. Scientific tests prove that they are smoother, more firmly packed and easier on the digestive tract."). It is unlikely that the Russians publish any journal like *Consumer*, which advises the reader on the quality of products in the shops.

Variety of formula and institution is a further virtue of the American way of life. It leads to a high turnover of ideas and to rapid evolution, since in biological terms there is not only greater scope for interbreeding of ideas, but natural selection has a wider range of ideas on which to operate. Salvador de Madariaga, writing for the United States Information Service, has put the case for variation and inequality in forceful terms.

" Man's evolution is the spearhead of the evolution of life, which in turn sets in when physical evolution is well advanced on our planet. Now, the chief point is that the evolution of life brings into the world a principle and a trend in reverse to that of physical evolution. The evolution of matter tends ever towards disintegration, pulverisation, equalisation. Hills get eaten up by the wind and the rain, seas and rivers get filled up, temperatures get even, and in due course, all ends in a dead, desert-like equality of grains of sand, all the same, all sterile. Life, however, evolves exactly the opposite way. The amoeba becomes every century more complicated, and gives rise to the lichen, the plant, the animal, man. So, from the amoeba to the Sistine Chapel or the Ninth Symphony, life waxes every day higher, more complex, more independent from direct physical requirements, more unlikely, more unexpected, more original, differentiated, creative. This is our challenge to-day. There are those among us who would have us all become equal: all like grains of sand in a desert. That way lies communism. And that way also many misguided forms of strictly equalitarian socialism. These leaders and advisers would drive mankind back to the mineral. They are blind to the true law of man's evolution. Then there are the nationalists. They would guide us back to the herd. For these people, a nation is like a herd of elephants, of buffaloes or of giraffes; and they remain incapable of rising above the interests and power of their own kith and kin. These people are not as reactionary as the communists, for they would not drive mankind back as far as the grain of sand; but they certainly would drive it backwards, towards the animal. The challenge of our day demands that we should give up the dream of deadly equality and the nightmare of murderous nationalism, in order to rise to the conception of a well organised mankind, conscious of its common spirit, and constituted in tiers of federations of free communities capable of co-operating in peace and liberty."

LIKE POLES?

At the present stage of the contest, the Soviet effort is directed to catching up the United States, and it should be borne in mind that where the direction is known, it is far easier to allocate resources. A greyhound may conceivably overtake the hare it pursues but will subsequently have less cause for effort and may even lose its way. If the Soviet Union comes level with the United States, then the problems of overproduction and the economic distribution of resources will be as severe in Russia as in America, except that for the Soviet worker, hardship will be in the form of an enforced uprooting. The danger to America lies in the power of the Soviet authorities to subsidise uncommitted countries at the expense of its own population, and the possibility that the United States may be driven to fight the enemy with the enemy's own weapons. As a result America may acquire some of the Soviet Union's less desirable qualities.

Already there are likenesses. A couple from Illinois told me that they would have been far happier in " horse and buggy days," and it reminded me of a Russian lady I encountered, who looked back nostalgically to the " days of candles and carriages." I was told that in certain American prisons, television was used to watch the prisoners and in nurseries to eavesdrop on the activities of children, both examples recalling the mood of 1984; while Mr. William H. Whyte's reference to " prose engineers " suggested a similar context. The tremendous scale on which purchases are made on the instalment plan has not only been blamed for the recession, but sometimes also serves to deprive the owner of a secure sense of possession, a tension which must be familiar under communism. The practice of checking up on the wives of candidates for managerial promotion also suggests the climate of a totalitarian community. " Labor is prior to and independent of capital. Capital is only the fruit of labor, and could not have existed if Labor had not first existed. Labor is the superior of capital and

What They are Thinking and Where it Leads

deserves much the higher consideration . . . " These are the words not of Karl Marx, but of Abraham Lincoln.

No doubt these are superficial instances, and in any case similarities between West and East are not invariably sinister. But in recent years we have seen Sinclair Lewis's *It Can't Happen Here* almost brought to life, and although that chapter now seems closed, an atmosphere of desperate international rivalry could revive it.

I seem to have argued myself into foreseeing a form of corporate state as America's destiny, a prospect almost as sinister as 1984. But it is always worth bearing in mind that reality comprises a lot of details, and an abstract analysis on one plane is often meaningless when viewed from the active busy plane on which we live. It would be naïve to suggest that America will shortly become communist or that the Soviet Union is about to embrace capitalism, but I am not alone in believing that both are moving towards some common compromise with nature. Dean Harrison has suggested a similar process of evolution in his remark quoted in an earlier article concerning the tendency of corks to float and stones to sink.

DREAM WILL HAVE TO GIVE

Pragmatism, the philosophy I have described as peculiarly American, applies the test of will it work or won't it? In the case of Mr. Khrushchev, we should probably describe the same approach as opportunism. But in fact pragmatism is virtually a law of nature, and the human race has been notorious for abandoning views and impediments incompatible with the times, cutting off the dead branch, in Carlyle's phrase, to preserve the living tree. The false elements of Marxism at present apply too rigid a restraint on Russian evolution, but already there are signs that where the situation calls for certain measures, Marxism gives way. Similarly in America: in the words of William H. Whyte, Jr., " it is the American Dream that is going to have to give . . . . People grow restive with a mythology that is too distant from the way things actually are."

Americans have the initial advantage in that not being hamstrung by a philosophical system, they can carry common sense to its proper conclusion. Applied common sense manifests itself in many ways: because of the sensible almost mechanical procedure used in issuing American visas, the process takes rather less than 20 minutes. A similar Soviet clearance needs several weeks. What is more, the American is accustomed to unconventional and counter-current thinking, though what Mr. Adlai Stevenson has described as " old snarling rituals " sometimes induce an overlay of uniformity.

But such restrictions on his liberty of thought are not taken seriously by the average American, whose desk may carry the pasteboard satire " No reason—company policy," or the miss-spelt plea to " THIMK." The Americans, like the English, are also quick to adopt whatever is useful in other people's traditions and practices, though recently the Russians too have shown a genius for imitation. America has in addition a long and prolific experience of trial and error, an approach which may be dangerous in Russia.

DIRECTION OR DEGREE

Perhaps the essential difference between the American and Russian systems is that the former generates immense vitality but uses it in prodigal and random fashion, while the latter evokes less energy but channels it more carefully. There appears to be room for compromise. Certainly we are entering an age in which it is necessary for a nation to aim at what it wants—aim off a little for wind perhaps, but aim nevertheless. No longer can we afford to create a sprawling wealth by the fortuitous interplay of economic forces; rather we must direct our energies to purposes deliberately chosen. In this respect, the Soviet Union's largely centralised control may show to advantage, as in its determination to train an abundant number of scientists and engineers. But its concomitant weakness may well outweigh the benefits. Research, for example, often yields more valuable results when left to follow its nose. It is perhaps time for a redefinition of what men may demand from society and what society requires of them. America has started to ask some salutary questions; Russia, with its official set of values, has not yet reached the point of self-awareness.

Dean Harrison, like most Americans, is not discouraged. He concluded a recent address with the following remarks. " I think that things are getting a lot better actually. It reminds me of the Italian who came over to America from the old country, set up his shoe-shine parlour and at the end of many years had saved enough money to send back to Italy for his wife, Maria. He had become a citizen of America, and he wanted Maria to be an American citizen too. So he wrote Maria that she should learn English. When they met on the dock he embraced her, and she said a few words in broken English. He said, ' Oh, that's-a fine Maria! You be an American citizen too very soon.' But as they were going along, leaving the dock, she listened to what people were saying around them, and said to her husband, ' Theese-a people no speeka good English.' He paused: ' Ah yes, Maria, but they're getting better. You should-a heard them when I came over! ' "

TO SEE WITH

I returned to England reassured. There is nothing wrong with America that Americans can't cure. Inevitably their society, like ours, must adapt itself to new conditions, but the values by which society is measured will remain unaltered. Like the Russians, the Americans have been described as materialists, but this is far from true. In his poem *The Star Splitter*, Robert Frost reveals an aspect of Americans that is sometimes overlooked.

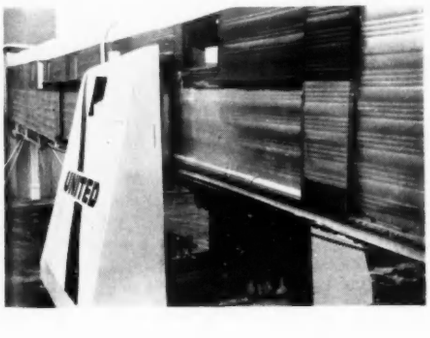
" What do you want with one of those blame things? "
I asked him well beforehand. " Don't you get one!"
" Don't call it blamed; there isn't anything
More blameless in the sense of being less
A weapon in our human fight," he said.
" I'll have one if I sell my farm to buy it."
There where he moved the rocks to plow the ground
And plowed between the rocks he couldn't move,
Few farms changed hands; so rather than spend years
Trying to sell his farm and then not selling,
He burned his house down for the fire insurance
And bought the telescope with what it came to.
He had been heard to say by several:
" The best thing that we're put here for's to see;
The strongest thing that's given us to see with's
A telescope. Someone in every town
Seems to me owes it to the town to keep one.
In Littleton it may as well be me."

To me these lines epitomise the American's curious combination of the practical and the visionary.

Talking to Americans

Reprints

The series of articles, Talking to Americans—What They are Thinking and Where it Leads, is to be reprinted as a booklet. Details of its sale will be announced later.



(Left) Atomic energy and public resources. Basic studies in a new technology may require Government facilities such as the Oak Ridge National Laboratory where this swimming pool reactor is located. The laboratory is operated for the Atomic Energy Commission by the Union Carbide and Carbon Corporation.

(Left) Spoiling the citizen. At Chicago a telescopic gangway pivots into position beside an aircraft to protect alighting passengers from rain.

(Right) Pacific ocean and Californian coastline.

Atomic Review

Water in Moderation

WATER is an attractive moderator for nuclear reactors, in particular since being fluid it can also be used as coolant; and there is reason to believe that its corrosive properties have proved less formidable than was once anticipated. Both light and heavy water are employed for this purpose, though in the case of light (or ordinary) water, it is necessary to burn an enriched fuel. Pressurised-water reactors and boiling-water reactors have now been operated successfully in the United States, sometimes over long periods, and in Britain construction of a prototype pressurised-water reactor plant has been undertaken at Dounreay. In addition, a heavy-water moderated gas-cooled reactor (see Atomic Review, 4 October, 1957, and 4 July, 1958) is under consideration, and in Norway, at Halden, a boiling-heavy-water reactor is nearing completion. Certain homogeneous reactors also employ water as moderator.

Horace and Herald and Light Water

Horace, a zero energy reactor, is now operating at the Atomic Weapons Research Establishment at Aldermaston, Berkshire. It is described as a facility for the study of the nuclear characteristics of a light-water research reactor. Horace consists of an arrangement of enriched reactor fuel in ordinary water. It will be used to investigate different types of reactor core arrangements and the use of different materials as reflectors (to reflect neutrons, which might otherwise escape, back into the core). Work with Horace should enable the time taken for full commissioning of a second Weapons Group reactor of the same class to be materially shortened, since tests with it will provide data relating to the control, safety, and core arrangements of this type of reactor.

This second reactor at Aldermaston, named Herald, is being built by A.E.I.-John Thompson Limited, and should be completed by the autumn of this year. This will also have ordinary water as moderator and coolant, will operate at power levels up to 5 MW and will be used for research with neutrons and for the production of special isotopes. There are now 35 reactors either in operation or under construction in the United Kingdom for research, testing and power production.

Heavy-Water Moderated Reactors Compared

A report by American-Standard Atomic Energy Division has been published giving an evaluation of heavy-water (D_2O) power producing reactors. The reactors considered are of the pressurised-water or boiling-water types in a range of sizes from 20 to 250 MW (electrical). No tube type reactors were considered. The following quotations, which have been taken from *Nuclear Technology Briefs—Power Reactors*, prepared for the United States Atomic Energy Commission by Dr. Walter H. Zinn and associates of the General Nuclear Engineering Corporation, Dunedin, Florida, give the principal results of the study.

Costs.—Firstly, over a wide range of operating conditions and economic situations, it is more economic at present to employ enriched uranium (up to perhaps 1·4 per cent U235) in heavy-water reactors than is natural uranium. The chief reason for this choice is that enriched uranium permits a sufficiently favourable combination of longer exposure time, smaller lattice spacing, and lower critical mass so that the savings in fuel-cycle cost and capital charges more than compensate for the higher cost of the enriched uranium.

Secondly, in the longer range, the use of natural uranium may become more economic as zirconium fabrication costs decrease, continuous charge-discharge devices are developed to permit longer exposure levels, and pressure-vessel technology advances so that the large critical masses and core diameters required are not such an economic penalty on the natural uranium. The results of this study agree quite well with the data and discussions of the Canadians on this matter.

Thirdly, both the relatively high capital cost and the additional charges for heavy-water inventory and losses make the economics of the heavy-water reactors more sensitive to size than for other types. A comprehensive analysis of the equipment requirements indicated that neither the pressure vessel nor the leakage restrictions present insurmountable problems. The costs shown in the accompanying table were estimated on the basis of a moderate amount of optimism that present nuclear fabricating costs will be improved somewhat. In the same size of 100 EMW and above, these costs are in the same range as slightly enriched light-water reactors. The small heavy-water reactor (20 EMW) has relatively high power costs, however, compared with possible light-water designs.

Canning.—The study also finds that the use of stainless-steel fuel-element jackets rather than zirconium

TABLE —*Costs for Boiling and Pressurised Heavy-Water Reactors*

	20 EMW		100 EMW		250 EMW	
	Boiling	Pressurised	Boiling	Pressurised	Boiling	Pressurised
Dol per kW	540	695	306	374	247	302
Mills (10^{-3} dol) per kWh						
Capital charge (15 per cent)	11·6	14·9	6·6	8·0	5·3	6·4
Fuel cycle cost	2·5	2·4	2·3	2·3	2·6	2·3
D_2O losses	2·1	1·7	0·8	0·7	0·6	0·4
D_2O inventory (12 per cent)	3·0	3·0	1·4	1·2	0·9	0·8
Operating and maintenance	1·8	1·8	1·2	1·2	1·0	1·0
Total	21·0	23·8	12·3	13·4	10·4	10·9

" is significantly cheaper, even at high exposure levels, on the basis of the fabrication costs for zirconium and stainless-steel elements used here."

Critical Characteristics.—The difficulties of arriving at a practical evaluation of a reactor type are by now rather generally recognised in the nuclear power industry. The great value of such studies is in examining closely the limitations of the reactor type, and in defining the characteristics which must be improved in order to reduce the cost of power generation. One study would indicate that the pressurised heavy-water (D_2O) reactor, like the pressurised water (H_2O) reactor, is apt to suffer from high fuel fabrication cost, and, further, that the costs associated with the use of heavy water (inventory costs and losses) are relatively important.

Assumptions.—In making an absolute evaluation of the reactor type, or a comparative evaluation with other types, it is always necessary to make some technical and economic assumptions which, at best, represent an extrapolation of past experience into the future. Often these assumptions have a large effect on the final evaluation. In this connection it should be remembered that fuel prices and reprocessing costs, although they have been established for certain periods by the Atomic Energy Commission, amount to assumptions for the long term.

Assumptions made having unique application to the D_2O case are as follow. (1) D_2O losses amount to 7 per cent per year for the pressurised D_2O reactor and 8·5 per cent per year for the boiling D_2O. It is stated that conventional equipment, modified with special seals and D_2O collection systems, would be used. (2) A D_2O inventory charge of 12 per cent per year is applied in the power-cost calculation of the table above. It is recognised in the report that D_2O can be rented from the USAEC at 4 per cent per year, and such an arrangement would seem to be consistent with the 4 per cent use charge on the fuel. The figures in the table above can be modified in an obvious way by a reduction of the inventory charge to 4 per cent. (3) The reactor designs considered are based on an average heat flux of 120,000 B.t.u. per sq. ft-hour, a value which is consistent with current practice in pressurised H_2O designs. It seems quite reasonable that higher average fluxes might be used in D_2O reactors, which are much less susceptible to " water-hole " effects, have larger reflector savings, and probably suffer less from flux distortion by control rods.

Dissent.—Dr. W. B. Lewis of Canada has expressed disagreement with the conclusions of the American-Standard report and, in particular, with the conclusion that power costs for D_2O reactors will be in the same range as those for slightly enriched H_2O reactors. According to Lewis, the potential advantages of D_2O reactors are obviated in the report by the following restrictions: (1) the assumption that high fuel fabrication costs, which presently characterise zirconium-jacketed fuel elements will prevail; (2) the consideration of pressure-vessel rather than pressure-tube reactor types; and (3) the use of one-batch fuel loading, rather than segmental loading.

Lewis takes the position that no reactor is worth development for central-station use unless it has the potential for competing economically with fossil-fuel plants. He argues that nuclear plants are unlikely to have capital costs as low as those of coal-fired plants, simply because nuclear plants are more complex. Hence, only the nuclear plant types which promise fuel costs lower than those of coal-fired plants are potential competitors. Quantitatively, he relates the permissible competitive fuel cost to the the capital cost by the following simple expression. For competitive operation, nuclear fuel costs must be equal to, or less than: $\left(3{\cdot}3 - \frac{CR}{876{\cdot}6\,u}\right)$ mills per kWh, where the quantity 3·3 mills per kWh is the approximate fuel cost for coal-fired plants burning expensive coal (8 dol per ton) in the United States or Canada; C is the extra capital cost of a nuclear plant, above that of a coal-fired plant, in dollars per electrical kW; R is the annual charge rate on capital investment as a percentage ; u is the plant factor ; and the constant 876·6 is simply a conversion factor which converts dollars to mills, and kilowatt-years to kWh. If the extra cost of the nuclear plant is 100 dol per EkW (which Lewis states is about the lowest figure for current proposals), if the capital charge is 14 per cent per year, and if the plant factor is 0·8, then the highest competitive fuel cost would be 1·3 mills per kWh, a figure which Lewis believes might be attained in a natural-uranium D_2O reactor, but which is unlikely to be attained in enriched H_2O reactors.

Corrosion Handbook and Residual Problems

Reference was made in ENGINEERING last 27 June (p. 823) to the *Corrosion and Wear Handbook for Water Cooled Reactors* sponsored by the Naval Reactors Branch, Division of Reactor Development, USAEC, and published by the McGraw-Hill Book Company. In a foreward to the handbook, Admiral H. G. Rickover, Chief, Naval Reactors Branch, writes: " our basic understanding of water technology is weak. We do not fully understand, for example, the processes by which metals become dissolved or suspended in the reactor cooling water, how the radioactivity is then transported to the external system and how it is deposited on surfaces. We cannot be sure that changes in temperatures, flow rate, or chemical condition of the water will not lead to fouling of heat-transfer surfaces, increased radioactivity in external systems, sticking and galling of water-lubricated mechanisms, or other deleterious conditions. We know that such problems can arise and we do not know all the causes and conditions which can create them nor can we assure their prevention. In future plants, differences in operating conditions now thought to be unimportant could mean the difference between a practical power plant and an expensive toy."

Heat Transfer for Water Processes

The properties of a plot of the isotherms and phase boundaries of water-steam-air mixtures on an enthalpy-composition diagram for constant total pressure permit graphical constructions enabling surface conditions, heat and mass transfer rates, and equipment size to be deduced

for convection, steam-drum and radiant drying plant, cooling towers, condensers, gas coolers and trickle coolers. This is demonstrated in a paper recently presented before the Institution of Mechanical Engineers by Dr. D. B. Spalding. A chart for atmospheric pressure calculations was given, together with data from which charts for other pressures may be simply calculated. The graphical method may also be applied to other systems involving phase changes.

Boiling Water Reactor with Superheater

The USAEC has signed a contract with the Nuclear Products-Erco Division of ACF Industries, Inc., Washington, D.C., to develop and construct a demonstration nuclear power plant at Elk River, Minnesota. The Commission is negotiating a contract with the Rural Co-operative Power Association at Elk River under which RCPA would provide a site for the nuclear plant, the conventional turbo-generator and related facilities, operate the entire plant for five years as part of its electric power system and purchase from the Commission the steam produced by the reactor. The agreement with ACF covers design, development, fabrication, construction and test operation of a closed-cycle boiling-water nuclear reactor and conventional fuel-fired superheater with a combined capacity of 22 MW electrical. The reactor would use water as a moderator and coolant, and a mixture of thorium and uranium oxide as fuel. The reactor would be completed by 1960.

Steep Power Rise in Water Boiler

The USAEC's nuclear research reactor, known as the kinetic experiment on water boilers (KEWB), increased its power output from zero to 530 MW thermal in less than a second and then shut itself off without sustaining any damage in a recent experiment. This rate of power increase is said to be the largest known to have been experienced safely by a reactor and amounted to tripling the power every two-thousandths of a second. The power surge occurred in a special test to study the behaviour of an aqueous homogeneous reactor if operating control were lost. KEWB was designed and built and operated for the Atomic Energy Commission by Atomics International, a Division of North American Aviation. It is a 50 kW aqueous homogeneous research reactor fuelled with a solution of uranium 235. The power surge was so brief that the temperature of the fuel solution was raised only slightly, not enough to cause it to boil. Only moderate pressure lasting for one-thousandth of a second was generated within the reactor vessel. The power was prevented from rising further by the sudden expulsion of fuel solution into an overflow chamber which prevented the nuclear chain reaction from continuing. The expulsion of the fuel solution, in turn, was caused by generation of gas within the fuel, a characteristic of solution-type reactors under high power operation.

Power Reactor for Alaska

Alco Products, Incorporated, New York, have obtained a contract for the entire nuclear system of Alaska's first atomic power plant to be erected by Peter Kiewit Sons and Company of Omaha for the U.S. Army Corps of Engineers at Fort Greely, near Fairbanks. The proposed 1,700-kilowatt pressurised-water plant will be based on a design prepared by Alco Products, Incorporated, under a contract awarded by the Army early in 1959. Similar in design to the Army Package Power Reactor (APPR-1) built at Fort Belvoir, Virginia, APPR-1A, as the new reactor has been designated, will produce twice the heat of the prototype, half the thermal output being used to generate electricity (1,500,000 kWh per lb of enriched uranium), while the other half will be used for space heating. Humphreys and Glasgow Limited hold rights for plants of this kind outside North America.

Power Reactor for South Carolina

The USAEC have announced agreement with Carolinas Virginia Nuclear Power Associates as the basis for contractual arrangements for a demonstration nuclear power plant at Parr Shoals, 25 miles north of Columbia, S.C. The agreement will cover design, development, fabrication, construction and test operation of a heavy-water cooled and heavy-water moderated pressure-tube type reactor, with slightly enriched uranium as fuel. The power reactor will have a net electrical capacity of about 17 MW. It is expected that the reactor will become operative by 30 June, 1962. Under the proposed agreement the Associates would pay the capital cost, about 22,000,000 dol, while the total cost to the Commission will be about 14,655,000 dol for research and development programmes and fuel for the first five years of operation.

EBWR Shut Down for Repairs

The experimental boiling water reactor (EBWR) at the Argonne National Laboratory of the Atomic Energy Commission, Lemont, Illinois, has been shut down because of excessive vibration in the turbine generator. The turbine has been removed, and examination by the turbine manufacturers' representative disclosed that one turbine blade and its shroud were missing. Further investigations to determine the extent of the damage are in progress.

Notes and News

Commonwealth Nuclear Scientists

There is to be an informal meeting of Commonwealth nuclear scientists in September this year, the Prime Minister recently announced.

Progress and Goliath at Hunterston

The foundations for the first reactor of the Hunterston nuclear power station have been completed and work on the reinforced concrete superstructure is proceeding on a two-shift system to meet the programme. The imposed load of the reactor structure, approximately 75,000 tons, is carried to bed rock by means of a 7 ft 3 in thick reincorced concrete raft cast in three lifts upon mass concrete fill. (In this station, charging and discharging of fuel will be carried out by a single machine operating beneath the reactor.) The walls of the reactor building are now approaching the level of the charge-room roof, some 42 ft above ground level. This roof will form the lower surface of the 6 ft 6 in thick concrete shield beneath the reactor pressure vessel.

Progress is also being made on the turbine hall and on the circulating water system, which is designed for a capacity of 324,000 gal per minute with an intake velocity of 1·5 ft per sec and a velocity of 5·5 ft per sec in the offshore intake culverts. Welding of the pressure shell for the first 80 ft long 20 ft diameter steam-raising unit is well under way, and work is also proceeding on the 70 ft diameter 3 in thick spherical pressure vessel for the first reactor. A Goliath crane, with 200 ft clearance from ground to bridge, and also between its legs, is also nearing completion. It is designed to lift 300 tons or in special circumstances 350 tons.

Goliath crane of 300 tons capacity with a span and height greater than 200 ft. It has been designed for lifting major items of the Hunterston nuclear power station. (G.E.C.—Simon Carves).

The station, which will have an installed generating capacity of 360 MW and an ultimate net electrical output of 320 MW, is being built for the South of Scotland Electricity Board by the General Electric Company Limited in association with Simon-Carves Limited, the Motherwell Bridge and Engineering Company, Limited, and Mowlem (Scotland) Limited. The first reactor is scheduled to become critical early in 1961, and the second approximately twelve months later. Construction began nine months ago. The crane was designed to GEC specification by Societé Applevage of Paris, who supplied the structure.

General Manager of USAEC

It has been announced that Major General Alvin R. Luedecke of the United States Air Force is to succeed Mr. K. E. Fields as General Manager of the USAEC.

Calder Turbine Disintegrates

A turbine in the northern generating house at the Calder Hall B power station disintegrated, causing extensive damage, on Saturday, 28 June. It had been started the previous Wednesday. No one was hurt. The UKAEA has convened an inquiry under the chairmanship of Mr. P. T. Fletcher, deputy managing director of the Authority's Industrial Group.

Windscale Final Report

There seems reason to believe that No. 1 reactor at the Windscale plutonium factory, which sustained damage during a Wigner release last year, will not be restored to operation; and that No. 2 reactor will require extensive modifications, possibly costing £500,000, if it is to be restarted. Last week was published the final report of the committee under the chairmanship of Sir Alexander Fleck which was appointed by the Prime Minister to make a technical evaluation of the Windscale piles and the factors involved in the controlled release of Wigner energy. The circumstances of the accident were described in Atomic Review last 15 November, and an article by Dr. P. J. Grant considering Wigner effect was published in ENGINEERING 24 January '58, p. 120). A summary of the committee's recommendations and conclusions are reprinted below.

It is recommended that steps be taken to prepare for the release of Wigner stored energy in Windscale Pile No. 2 by the combination of the slow heating method and the BEPO technique first carried out in March this year. The release should be performed when the improved instrumentation and other modifications proposed have been installed; thereafter the reactor should be operated normally subject to modifications in procedure recommended. A possible alternative would be to operate the pile without planned releases under conditions applying strict control at all times to graphite temperatures, but this would restrict the flexibility of operation of the reactor, and the method suggested above is therefore preferred.

The committee recommend the following modifications in the No. 2 reactor. A substantial increase in the number of instruments is required, particularly for the purpose of measuring the temperatures in the graphite and fuel. Apparatus for the detection of fuel-element failures must be available at all times. The existing filters should be improved. The existing design of fuel cartridge is satisfactory, but the present design of lithium/magnesium cartridge is unsatisfactory. A full study must be made of the performance under all conceivable pile operating conditions of all materials used for the production of isotopes, for experimental purposes, etc., before they are inserted in the reactor. There is no need for a release of Wigner energy from the Calder Hall reactors for at least two years.

The Human Element

A Taste for Sandwiches

The " sandwich " course as a means of training engineers is admirably suited to the British temperament. Like the original sandwich from which its metaphorical name derives it often has in it a little bit of everything and no one really knows what it is all about until it has been sampled. It has for the British all the fascination of the empirical approach. It is a judicious mixture of practical training and formal education. It keeps (or at least is intended to keep) a trainee's feet firmly on the ground. Theory is rubbed smooth against practical experience and no one, says the older school, is allowed to get too long haired. Its final appeal to us is that it is a device, acceptable in its own right, which looks as though it is going to be admirably suited for dealing with an emergency. In short, it does not look very tidy at times but it works.

Its popularity, needless to say, is growing. According to a list published by the Ministry of Education (H.M.S.O., price 1*s.* 6*d.*) there are to be 263 such courses held during the 1958/59 session which will be 65 more than last year. The increase is both at colleges of advanced technology and regional colleges and at the other technical colleges. Their popularity and standing both among employers and students is on the increase.

Training on Display

Increasingly, large companies are publicising their training facilities. This is a good sign. It shows that they know that they have something to talk about and that there is competition for youngsters to train.

Babcock and Wilcox Limited have recently announced the completion of a large new educational and training centre at Renfrew in Scotland. This is the culmination of 13 years of organised training for craft apprentices and undergraduates. There are now about 760 apprentices in various stages of training at Renfrew.

In London, Mullard Limited have held an exhibition this week to publicise the Mullard educational service to schools and technical colleges. All aspects of the service have been displayed and there has been a programme of instructional film and filmstrips. These kinds of displays can be a valuable weapon in the armoury of those who are trying to kindle an interest in the young in various branches of engineering.

Vital Link

The function of the supervisor in industrial management is the central theme of the recent report of Regional Conferences of Industrial Supervisors entitled *Supervision—Management's Vital Link*. This is a 75-page collection of papers by managers at various senior levels, each examining a particular aspect of supervision. Lt.-Gen. Sir John Evetts, managing director of Rotol Limited, writes the introductory paper on " The Supervisor and Modern Management," in which he examines the radical change that has taken place in industry since the war, particularly the impact of full employment on managerial policy and that of rapid technical advances on the need for better training facilities. But, he said, " we must not stop at the training of new recruits. Those of us in industry must continue to become more efficient by adopting new methods and techniques, and by adapting ourselves to them quickly."

A paper by Dr. W. G. Hiscock, the director of operations of Imperial Smelting Corporation Limited, examines the duties of the foreman under the heading of " Teamwork—the Pattern of Modern Industry," and concludes that it is necessary to make foremen aware of their responsibilities and to define clearly the duties they are expected to carry out. His list of duties is comprehensive and specific.

Sixteen other papers make up what is a thought-provoking and enlightened document. It achieves most effectively what Mr. H. A. C. Tracey, general secretary of the Institute, describes as the main objective of the book, namely " to demonstrate the key position which the supervisor occupies in the management chain."

The Three Graces

Addressing the Personnel Management Conference recently at Cambridge, the Hon. Richard Wood (Parliamentary Secretary to the Ministry of Labour) said that progress in maintaining the prosperity of this country depended largely on three things. These were the expansion of training facilities, the reduction of time lost due to injury and the improvement of personal harmony throughout industry. He was speaking on the theme of human relations as the key to high productivity.

In these days when so much is said about the need for good human relations, it is often forgotten that they are no more, in a sense, than one aspect of good management. Any manager who stops to think about it is aware that it is easier to lead a team of human beings whose self-respect has been appealed to and who know where they fit into the scheme of things than to goad on those who are driven by purely impersonal sanctions, by the pay packet at the end of the week and no more than the pay packet.

From that point of view, therefore, good relations are a question of imagination and good communication, which in turn is a question of organisation. The more the different aspects of management are separated into their constituent parts for analysis the more they are seen to hang together. This is equally true of the human-relations aspect. It is part of a whole and no more than that, and has to be reconciled with good discipline. A " soft " labour policy is not a good policy and intelligent trade unionists know it.

Healthy Concern

The task of safeguarding the health of industrial workers was the subject of a travelling seminar set up by the World Health Organisation and held recently at the headquarters of the Ministry of Labour, having previously met in France. Specialists in industrial health from 21 countries attended. The object of the seminar is to provide an insight " into the practical working of industrial health with a view to improving working conditions and the health of the workers." Great Britain and France were chosen as fields of study because of the high standard of their health organisations.

Delegates were given information on the systems of occupational health in the two countries and asked to fill in a lengthy questionnaire which is being analysed by the Regional Office for Europe of the W.H.O. In France, the delegates were impressed by the comprehensive and progressive legislation passed by the Government to ensure that workers exposed to hazards undergo frequent medical examinations and by the elaborate medical service provided by the building and coal-mining industries. In this country they found a great deal to admire in the progress made in the prevention of occupational ill-health and accidents. Most of them had seen nothing to compare with the Slough Industrial Health Service.

There has been a complete revision of the schedule of occupational diseases for which workers in specified occupations are covered for the benefits of the Industrial Injuries Act. The regulations implement the recommendations of the Industrial Injuries Advisory Council made in their recent report on the Review of the Prescribed Diseases Schedule (Cmd. 416) and which came into operation on July 7. Alterations have been made in view of developments in medical knowledge and in industrial techniques, and represent a major advance in industrial injuries insurance.

Cars for Employees

While the battle rages over who is to secure control of the Standard Motor Company Limited, the company has announced a scheme for selling its cars on attractive terms to its workers. All employees with more than a year's service are to be allowed to buy cars from the company at a discount which in the case of long-service employees is a significant one. There are to be hire-purchase terms available and spares can be bought through local distributors at a substantial discount. The only stipulation is that the vehicle must not be sold within twelve months of purchase.

This is one way of moving car stocks though it seems to take with it, to judge from the terms to be offered on spares, much of the profit out of the sale of spares and parts, which is usually considered to be of critical importance to the car companies. From the general point of view it will be interesting to see if the useful reduction offered will stimulate sales significantly. There has always been a school of thought in this country which has said that if the price of cars came down to any extent a new and large market would be tapped—which has been one reason why the Government has kept purchase tax on cars in the present state of the roads. A valuable clue may be forthcoming however as to whether this country can build up a car population of well over 5 million.

Professional Aunt

A little green book just published under the title *The Professional Classes Aid Council—Annual Report* is fascinating evidence of the vulnerability of professional people to ill winds, bad luck, or simply lack of funds to finish the long road to the established practice of their profession. Assistance with the fees of children at boarding schools, for widows unable to pay, the tiding over of elderly professional people who are ill before their pensions are due, the supplementing of state retirement pensions, and giving a helping hand to allow young people time to qualify, are examples of the type of help given by the Council.

The Council's income is very restricted—£21,157 in 1957/58—and the calls on their resources are very heavy. They are obliged therefore to confine their help to critical situations and not even to all of those which are brought to their attention. The report quotes many cases under various headings such as relief work, permanent help, temporary help, education and training. Reading through these brings home most forcibly the statement in the short introduction to the report, that the professional classes are " a section of the community which has relatively suffered as much as any from the economic changes of the past three decades." The Council's main endeavour is to set professional men and women on their feet again, and to see them through their difficulties by judicious temporary financial aid and by advice. In cases of old age or infirmity, it is " to enable life to be lived in modest comfort."

The patroness of the Council is H.M. Queen Elizabeth the Queen Mother. If in fact the need is so great, it is difficult to understand why so little is being done officially for the effectiveness, status and dignity of our professional classes.

Continuing **The Human Element**

LEARNING TO USE CALCULATING MACHINES

Speaking last week at an organised tour of the training establishments of the British Tabulating Machine Company Limited, the chairman, Sir Cecil Weir, remarked that training is a necessary and integral part in the manufacture of all types of automatic calculating machines. This is bound to be so as these machines become increasingly complex; operating them is no longer a matter of learning a simple drill. Ideally, it is a question of having the necessary qualified staff to programme them, deal with immediate emergencies and to be able to do a certain amount of maintenance, though in many cases these duties are carried out by the manufacturer's service staff.

As the age of the computer advances, it becomes necessary to ensure that these machines (and they are expensive to run below capacity) are kept fully employed, and this means knowing how to use them to best advantage. It is also necessary to recognise the right kind of machine to choose for particular purposes. Buying and loading a computer is an exercise to which at least as much attention should be devoted as buying and loading an expensive machine tool.

British Tabulating Machines have tried, with some success, to cover all these requirements. The company's name is associated historically of course with Hollerith punched-card equipment which was developed by the use of electrical as opposed to mechanical techniques in the tabulation process. To-day, through the Hec general-purpose electronic computer the company are in the computer field as well. It is therefore covering everything in connection with training and appreciation, from routine punching and verifying to programming a computer.

Its training facilities are extensive. There are six training centres. Moor Hall at Cookham is devoted to instruction in Hollerith electro-mechanical and electronic punched-card equipment and applications. Also at Cookham is The Grange where a residential course for executives on broad computer developments is held. Moor Hall is increasingly becoming used for appreciation courses for managers as well as for operators and programmers. At Bradenham Manor the course deals mainly with computer programming, refresher courses and electronic calculator programming, and it supplements the resources of the Hollerith Computer Centre in London. This centre is concerned mainly with demonstrations of computers in their various aspects and is non-residential. Finally there are engineering training schools (both non-residential) at Letchworth in Hertfordshire and at Castlereagh in Northern Ireland. Training here is supplemented by attendance for one day and one evening at a local technical college.

During a single year 2,000 people are trained at Moor Hall of which about 75 per cent are customers' staff. Some 600 people are trained each year at Bradenham Manor. In any one year about 250 apprentices are undergoing training within the company. There are four kinds of apprenticeship courses, each of which takes four or five years.

Other services offered by the company include about 300 organised lectures a year in the United Kingdom and a mobile exhibition unit which visits about 60 towns a year.

Bradenham Manor where the British Tabulating Machine Company hold training courses.

Automobile Engineering

By Gordon Wilkins

GERMAN MINIATURE CAR TO BE MADE IN ENGLAND

York Noble Industries Limited, 33 Park Lane, London, W.1, announce arrangements for production in England of the Fuldamobil three-wheeler economy car, some 12,000 of which have been made in Germany. It will be offered as a coupé with body of resin-bonded glass fibre or as a multi-purpose light truck with a canvas tilt which can be used for goods transport or for camping.

The tubular chassis carries vertical guides for the front wheels which are suspended on coil springs. The single rear wheel is carried on a swinging arm, also with a coil spring. The engine, which will be imported from Germany, is a Fichtel and Sachs air-cooled two-stroke of 191 cc giving 10 b.h.p. Transmission is through a four-speed gearbox with an electrically controlled reverse obtained by reversing the direction of engine rotation; the final drive is by enclosed chain. Brakes are mechanically operated. The coupé weighs about 660 lb dry, and the open car about 550 lb.

The 10 b.h.p. Fuldamobil is now to be built in England.

DAIMLER ACTIVITY INCREASING

The Daimler Majestic, announced last week, is frankly an interim model intended to keep the company in the passenger car market until decisions are made on the possible production of completely new models now under study; however, at a price under £2,500 including tax, it should find a ready sale. It is developed from the One-O-Four, with re-styled body, larger engine, automatic transmission and disc brakes. By re-tooling doors, centre pillars and rear wings, the body has been converted into a full six-seater of more modern appearance, and re-arrangement of the toolkit stowage has given slightly more luggage space.

An increase in bore from 3·25 in to 3·4 in (86·36 mm) has raised engine swept volume to 3,794 cc, and maximum power is now 147 b.h.p. at 4,400 r.p.m., with maximum torque of 209 lb-ft at 2,800 r.p.m. This should give a maximum speed of over 100 m.p.h. Manufacturing costs have been reduced by eliminating separate cylinder liners. Oil pump capacity has been increased and control linkages for the twin SU diaphragm-type carburettors have been simplified. The Borg-Warner automatic transmission is now standardised and this has permitted a reduction of the hump in the front floor, as on the previous model this had to be dimensioned to allow clearance for the optional fluid coupling. A control on the instrument panel allows the intermediate gear to be held in traffic or on hills.

The Daimler Majestic has a 3,794 cc engine developing 147 b.h.p.

Another cost-saving measure is the elimination of centralised chassis lubrication, but maintenance is simplified by the adoption of rubber bushes for the rear spring shackles. Front suspension is the André-Girling system as before. This uses coil springs and telescopic dampers. At each side there is a short upper radius arm and below are very wide-based wishbones with one transverse arm and one arm parallel with the side member of the cross-braced chassis. Dunlop disc brakes with circular pads are fitted to all four wheels and are assisted by a Lockheed vacuum servo.

The all-steel coachwork is being made by Carbodies, now a Daimler subsidiary, and an output of about 20 a week should be possible. Carbodies are also making 100 convertible bodies a week each for Ford and the BMC. Small quantities of the One-O-Four with fluid coupling and Wilson gearbox are being produced, and also the DK 400 4½-litre 7-passenger limousine, which has a composite body, with steel panels on a wood and metal frame made by Daimler.

Daimler are supplying armoured scout cars to NATO forces. They are also among the largest builders of chassis for double decker buses, mainly with diesel engines such as the Gardner.

It is known that a new car with a 2½-litre V8 engine has been under study for possible future manufacture and Mr. Edward Turner, who is now Daimler's managing director, has recently expressed a private view that such an engine, with pushrod valve operation, could be made to produce 165 b.h.p. reliably in a production version, but the new board is certainly not likely to embark on anything which could prolong the Daimler habit of losing money on car production. To produce quality cars economically would require extensive re-equipment of the engine works, new production lines and conveyor installations, besides the cost of press tools, jigs and fixtures. Through its ownership of Carbodies, who are able to produce steel bodies in quantity, Daimler are better equipped to survive than most of their rivals outside the Big Five, but it seems probable that the board will have to find a further £10 million or more for re-equipment if the company is to stay in the passenger car business on a long term basis.

In Parliament

AIRCRAFT OF THE FUTURE?

Reference was made in the House of Commons last week to the proposals which have been put forward by Vickers-Armstrongs Limited for an experimental aircraft embodying the principles of variable geometry. Mr. Frank Beswick (Labour/Co-operative), a former Parliamentary Secretary to Ministry of Civil Aviation, invited the Minister of Supply to make a statement, in view of the exaggerated reports which had been made about the proposals.

He inquired whether it was a fact that, instead of there being just one design involved, there were a number of ideas which might or might not be best developed in one aircraft. Before making any final decision with respect to the development of the Swallow aircraft with financial aid from the United States, would the Minister make a further detailed statement regarding the proposed terms upon which that aid was to be made available?

The Minister should take into account the position that there were many people in this country who felt that ideas had gone across the Atlantic for development in the United States without this country getting very much in return.

CHANGING SHAPE IN FLIGHT

It was perfectly true, Mr. Aubrey Jones replied, that a number of principles were involved in the proposals for variable geometry aircraft. What had been at issue was how many of these principles there should be an attempt to incorporate at the first stage into a research aircraft. Should the project be an ambitious one to start with, or one a little more modest? The answer to that question depended, of course, upon cost considerations.

Whether the United States Government would feel able to support the Swallow aircraft project under the mutual aid programme was not yet known. If they did, the standard conditions agreed on between the two Governments, whereby commercial rights in inventions were safeguarded, would apply. It would be difficult to give the House the precise terms of any agreement that might be made because it would be an agreement between two companies, possibly in the form of a licence arrangement, and, as such, it would be confidential. It could be said, however, that most of the techniques involved had already been patented.

No proposals regarding these aircraft had come from the United States. The proposals had been made by the company and it would seem that the best course would be to await the answer from that Government. This particular variable geometry project, he told Mr. Roy Mason (Labour), had no special relevance to space travel. Asked to explain the term, Mr. Aubrey Jones said it referred to aircraft which varied their shape in flight.

FINANCING THE ROTODYNE

Progress regarding the Rotodyne aircraft, Mr. Aubrey Jones said, had been encouraging. The first prototype had been flying for eight months. It had recently achieved successfully the transition from vertical to direct forward flight, and it had already flown at forward speeds of up to 165 miles an hour. The aircraft had been designed to meet a requirement for a 40-50 seater inter-city helicopter, put out by British European Airways, and it was unique in its class. Its prospects for inter-city use, both in this country and elsewhere, were very promising.

Mr. N. N. Dodds (Labour/Co-operative) said there were authoritative reports that this aircraft, with its tremendous possibilities, was likely to be sold to American interests, owing to the difficulties encountered by the makers in finding enough money for its development in this country. Mr. Aubrey Jones said it was rather difficult to see how there could be any such concern. He had invited two firms, the airframe company and the aero-engine company, to submit their proposals to him for their financial contributions to complete the development of the aircraft. When this information was received, the Government would make up their minds about their contribution, and it was quite premature to speak of the possible demise of the aircraft.

COMPLICATED NEW THAMES BRIDGE

In the House of Lords, questions were asked by Lord Lucas of Chilworth (Labour) about the progress being made in connection with the Oxford Western By-pass. He expressed some surprise that this by-pass, which, he said, was to have only five bridges and one viaduct, was to take 28 months to complete, whereas the 53 miles of dual-carriageway motor road from London to Birmingham, which had 169 bridges, was to be completed, according to the Ministry of Transport, in 19 months.

Lord Mancroft, Minister without Portfolio, said that a comparison between these two schemes was not comparing like with like. The Oxford Western By-pass was a much more complicated engineering project than the London to Birmingham road. The Oxford project involved the construction of 13 bridges, including a very complicated one of 116 ft across the River Thames. It also involved the construction of the Wolvercut Viaduct, which was a major engineering project over the railway, the canal and the A.40 main London-to-Fishguard road, and was nearly 1,000 ft long.

The Berkshire County Council, who were acting as agents for the Minister of Transport, invited tenders for the project on 4 July. It was expected that work would start on 1 November and it was hoped that the by-pass would be completed by April, 1961.

BETTER POWER STATION CONDENSERS

A number of research problems were raised in the Commons. Mr. Bernard Braine (Conservative) wanted to know what was being done to improve the efficiency of condensers for power stations, and other heat-exchange equipment. He was informed by Mr. Harmar Nicholls, the Parliamentary Secretary to the Ministry of Works, that for some years research on heat transfer under varying conditions of steam condensation had been conducted by the Mechanical Engineering Research Laboratory at East Kilbride, as well as at various universities on behalf of the laboratory. These investigations had demonstrated that the condensation of steam on cooling surfaces as separate drops had great advantages in speed over the normal film condensation.

Chemicals had been developed which, when applied to brass or copper surfaces, produced what might be called "drop" condensation. The method had been tried out in the laboratory and, to some extent, in industry. If the method were proved to be really successful, it would mean that condensers need be only half the size they were at present.

APPLYING RESEARCH TO INDUSTRY

The Production Engineering Research Association, Mr. Harmar Nicholls said, was an autonomous body which was controlled by member firms and supported by the Department of Scientific and Industrial Research. In order to get research results across to industry, particularly at the shop floor level, the Association had developed an effective liaison and advisory service for its member firms, and it was spending one-third of its resources on that service. Short instructional courses, he told Mr. R. W. Elliott (Conservative), on new production techniques were held at the Association's laboratories at Melton Mowbray for foremen and works' executives. A mobile unit provided practical demonstrations and instruction in members' works. Furthermore, about 3,000 technical inquiries were answered each year. During 1957, about 1,650 persons had attended training courses at the laboratories and 150 visits had been made by the mobile unit. These services were available only to member firms of the Association.

Transmitting Electric Power

Mr. Anthony Kershaw (Conservative) raised the question of the transmission of electric power, saying that the country would soon become an "absolute birdcage" because of overhead cables, which looked disgusting and caused difficulties to the farming community. On this matter, Mr. Harmar Nicholls said that radio was not technically a feasible means of transmitting electric power and that the only economically practical method was by means of cables, either above ground or below. Research had shown that existing electric cables could carry a bigger load than they had been doing so far. One result of this discovery would be that the sums to be expended on new cables would be reduced.

Private Spending on Research

It was suggested by Mr. Frederick Willey (Labour) that there was a wide margin of error in the surveys made in 1955 regarding the amounts spent by private industry on research and development. He urged that the inquiries should be repeated and that, when they were, the Government should consider calling in the assistance of the Central Office of Information. Mr. Harmar Nicholls said that any statistical estimates of the amounts spent by industry in that direction were inherently difficult. The survey in 1955 was the first conducted by the Government in this field. If it were repeated, the methods then used would be improved in the light of experience. No plans had so far been made for such a repetition, as it was considered that the lessons to be learnt from the 1955 survey should be studied first.

Work for University Graduates

Arrangements had now been made, Mr. Harmar Nicholls said, whereby new standard forms for collecting and reporting statistics on the employment first taken up by university graduates would be used by university appointments boards for the academic year 1957-58. The adoption of these forms, he informed Mr. Frederick Willey, had been foreshadowed in the *Annual Report of the Advisory Council on Scientific Policy*, 1956-57 (H.M.S.O. Cmd., price 1*s.* 4*d.*). They were designed to provide more information than in the past and would indicate the numbers of British graduates who were taking up positions abroad. Instructions regarding the use of the new forms had been approved in March last.

Scientific Appointment to Moscow

A proposal was made by Mr. Alfred Robens (Labour) that, in view of the importance of scientific developments in Russia, the post of scientific attaché to Moscow should be regraded to the level of deputy chief scientific officer, which was the grading of the similar post at Washington. He felt that, unless the man appointed had a sufficiently high standing, he would not have the ear of leading Russian scientists. Mr. Harmar Nicholls replied that the post of scientific attaché to Moscow was being considered in the first instance in the grade of principal scientific officer. If a suitable candidate were not found, the best way of filling the post would be reconsidered.

Employment for the Elderly

Mr. Sydney Irving (Labour/Co-operative) asked the Minister of Labour about schemes for the employment of older workpeople. He was told by Mr. Iain Macleod that about a dozen firms were known by his department to have inaugurated special workshops or schemes for providing work for elderly persons who wished to continue in employment after the normal retiring age. In addition, about 20 special workshops for the elderly were being run by local authorities and voluntary organisations.

Research and Development

ASPECTS OF WELDING

Research Work at Abington Hall

The engineering research station and metallurgical laboratory of the British Welding Research Associaion (BWRA), Abington Hall, near Cambridge, were open to over 500 members and invited guests on Wednesday, 11 June. During the visit one was most impressed by the impetus which had been given to welding research by the new facilities provided by the Association and the growing awareness of industry to the importance of this kind of research in achieving more efficient productivity.

There were over 60 major exhibits on view representative of research investigations into such aspects as welding processes, metallurgical conditions and mechanical properties of welded joints, welded structures, and special components.

TRACK LINKS FOR SNO-CAT VEHICLES

Typical of the special investigations undertaken was the work for the Commonwealth Trans-Antarctic Expedition following the failure of some of the welded tubular track links of the Sno-Cat vehicles used in preliminary trials in Norway. After careful examination of the failures, all the original welds between the medium-carbon tubular links and cast-steel end fittings (Fig. 1) were cut out and remade by BWRA under carefully controlled pre-heating and cooling conditions. This was done by assembling in a jig, and preheating in a furnace at 500° C before electric arc welding using low hydrogen (E616) electrodes; the welded links were allowed to cool slowly, at a rate of about 150° C per hour in the preheat furnace. Mr. David Pratt, chief engineer of the Expedition who was one of the visitors, reported that all the 500 or so track units re-welded by BWRA had given good service without failure.

Much of the work at Abington has as its objective the assembly and analysis of data to formulate the design principles for welding fabrication whether it be welded steel frame structures for buildings, components used in chemical engineering or nuclear power plant such as pressure vessels and pipe lines with their branch connections. In support of the work under Professor J. F. Baker and his colleagues at Cambridge University towards the full development of the plastic method of design for welded frame structures, collapse load tests on full-scale structures were being carried out at Abington.

The tenth test in the series was seen in progress, the frame being a representation of a hangar-type portal, i.e. with a large span in relation to stanchion height (Fig. 2). The purpose of this test was to observe the effect on the collapse load of deflections just prior to collapse. It was found that the mode of collapse was in accordance with that predicted, the simple plastic theory giving an accurate estimate of the load at collapse without the necessity of making any correction for deflections. It was also interesting to note that the Association's laboratory buildings provide practical examples of welded frame structures based on the plastic method of design.

REINFORCEMENTS AND BRANCH CONNECTIONS

The importance of detail when designing welded structures to withstand fatigue loading conditions was the subject of an interesting exhibit in the fatigue laboratory, which showed examples of good and bad design; some of the latter had failed under fatigue conditions.

Fig. 1 One of the 544 welded track links (below) of the Sno-Cat vehicles (right) used on the Commonwealth Trans-antarctic Expedition. Following failures in preliminary trials in Norway all the welds were remade by BWRA and proved satisfactory throughout the expedition.

Modern stress analysis techniques were being applied to pressure vessels with branch connections subjected to pulsating pressure fatigue tests in order to determine the effect of conventional and experimental reinforcements on the stresses around the branches.

The pulsating pressure plant used for these investigations has been designed to operate continuously without manual control, and is provided with automatic cut-outs in the event of the test vessel failing or certain other changes in plant operating conditions to avoid loss of fluid from the plant. A servo-operated valve supplied the vessel under test with fluid from the main pump until the pressure equalled that in the upper limit reference vessel. The test vessel was then exhausted into the lower limit vessel, and the cycle repeated. The main pump was driven by a 75 h.p. electric motor, and an auxiliary pump and air compressor were used for the initial setting of the desired lower and upper pressure limits of the test within the range zero to 6,000 lb per sq. in; the rate of operation is up to 100 cycles per minute, depending on the capacity of the test vessel.

The present practice for heavy-walled vessels was to provide reinforcement to the branch connections proportional to the wall thickness, but mathematical analysis has suggested that for thick vessels less reinforcement should be required. If this proved to be the case, it would result in an appreciable reduction of fabrication costs.

To verify this theory a complete stress analysis of a 40 in bore by $4\frac{7}{8}$ in thick pressure vessel was in progress (Fig. 3). This vessel had been fabricated jointly by John Thompson Limited, Wolverhampton, who formed the shell, and Ruston and Hornsby Limited, Lincoln, who put in the branches of 8 in and 12 in bore. Pressure tests up to 3,000 lb per sq. in had been made and the stresses around the branches and ellipsoidal ends measured by electrical resistance strain gauges on the inner wall face and mechanical extensometers on the outer face.

Investigations into reinforcements for manholes in storage tanks had also suggested possibilities of reducing fabrication costs by discarding the large double plate which was, in conventional designs, welded to the tank, and inserting a tube

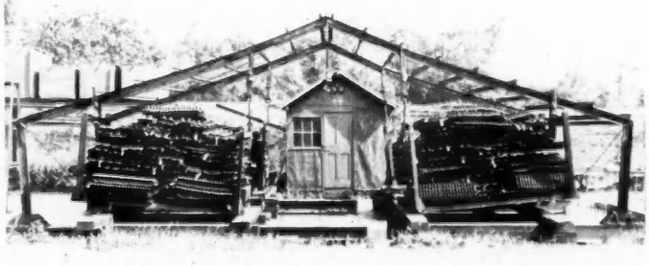


Fig. 2 (Left) Welded steel frame structure after it had collapsed under vertical loading test.

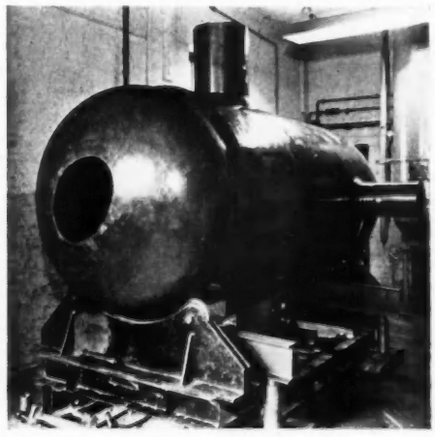


Fig. 3 (Right) Welded pressure vessel of 40 in bore and with branches, fabricated for pressure tests up to 3,000 lb per sq. in.

Continuing Research and Development

of suitable thickness through the tank wall. Similar experimental stress analyses of pipe branch connections and welded gussetted pipe bends had been completed.

PROCESS DEVELOPMENT

Notable advances made in recent years in the welding of aluminium alloys have been associated with the developments in inert-gas metal-arc welding. One of the difficulties associated with the use of high currents in this process was "puckering" due to turbulence in the weld pool. This limitation has been overcome by attention to gas shielding requirements and special nozzles developed by BWRA were exhibited which enabled higher currents to be used for welding aluminium alloy plate up to 2½ in thick. The nozzle displayed had a viewing aperture to assist alignment of the welding head with the joint. A general investigation into inert gas coverage with stationary and moving nozzles had enabled empirical formulae to be derived for the additional coverage length required for the latter depending on welding speed, cooling rate and head width (Fig. 4). To enable high-strength alloys such as HE15WP (Duralumin type) to be welded, a filler wire containing 7 per cent copper, 3 per cent silicon, 0·8 per cent magnesium, had been used successfully.

The advantages of being able to use HE15WP as compared with HE30WP for welded portal frames were demonstrated, the latter structure being at the point of collapse under the same load as was carried by the H15WP structure without failure. It was interesting to note that BWRA are producing a new handbook of radiographs, classified to assist in the identification and prevention of defects in aluminium fusion welds.

A new process for the welding of ferrous metals in which the metal-arc is shielded by carbon dioxide gas was being investigated. Using this process, satisfactory methods for welding ½ in thick mild steel plate and 16 s.w.g. sheet of SAE4310 (Cr-Mo) steel, have been developed.

Assistance had been given by BWRA in a number of resistance welding problems. For example, the fundamentals of spot welding were being studied in order to predict optimum welding conditions for hardenable steels with special reference to the effect of post-heat treatment on spot weld ductility. The spot welding of Nimonic alloys had also been investigated. A process had been developed to take advantage of "splashing" in spot welding which was generally regarded as an undesirable phenomenon.

Equipment for the semi-automatic welding of worn shafts by the overlay method was shown and the fatigue properties of 2 in dia. mild steel shafts reclaimed by this method were being investigated. An alternative method to the use of filler wire containing deoxidants for the automatic welding of thin-gauge phosphorus deoxidised copper, was also being investigated.

REACTIVE METALS

Special difficulties arise when welding reactive metals, i.e., metals such as titanium, zirconium, niobium, tantalum and vanadium, which are extremely reactive at high temperatures and in the molten state with gases such as oxygen, hydrogen and nitrogen. For these investigations BWRA had constructed a vacuum welding chamber which enabled test welds in these metals to be made under closely controlled welding and gas shielding conditions (Fig. 5). The chamber can be evacuated to 10^{-5} mm of mercury and filled with high purity argon. Although intended for tungsten-arc welding it is adaptable to the self-adjusting arc process. The torch is fixed, although height may be adjusted, and the workpiece, up to ½ in. thick and 12 by 9 in maximum overall size, is traversed smoothly by a pneumatic-hydraulic system at speeds ranging from 0 to 200 in per min.

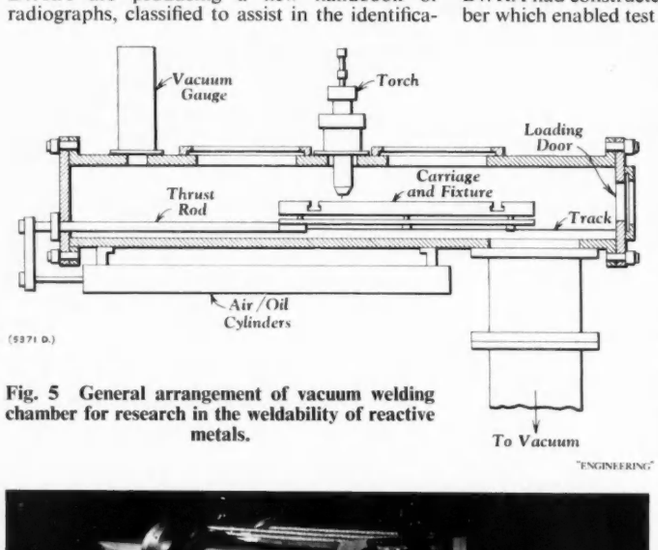


Fig. 5 General arrangement of vacuum welding chamber for research in the weldability of reactive metals.

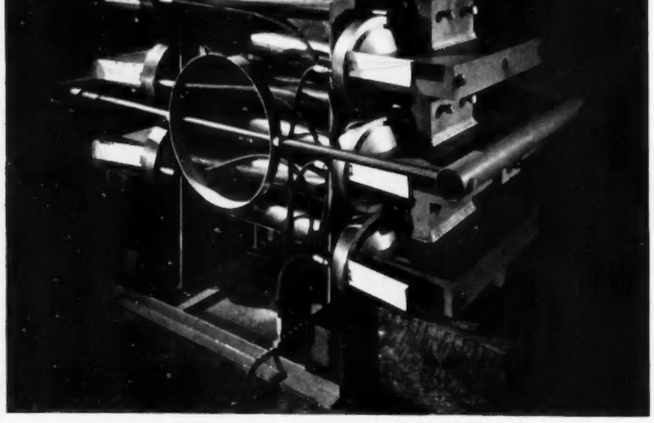


Fig. 6 2,000 ton tensile test rig for testing 36 in by 36 in by 3 in thick welded plate specimens in brittle fracture investigations.

Using this equipment it has been possible to determine the effect of polluting the chamber atmosphere with small quantities of air, on the mechanical properties of welds in commercially pure titanium. An argon-arc torch with a special shield has been designed to enable titanium to be welded under normal open air conditions. The effect of nitrogen pick-up in the area of welds in Zircaloy 2 on the susceptibility of this material to a particular type of corrosion after prolonged exposure to high temperature (330° C) water at a pressure of 1,850 lb per sq. in had been investigated. This material is used as a canning material for nuclear reactors and the results of corrosion tests carried out in an autoclave have shown nitrogen pick-up to be harmful.

Equipment had been built for determining the amounts of oxygen, hydrogen and nitrogen in metals such as titanium, zirconium and steel by vacuum fusion techniques. Polarographic equipment had also been installed and was especially useful for the analysis of small weld beads.

Modes of failure associated with welded structures under special conditions continued to be studied. Reference has already been made to the pulsating plant for the fatigue testing of pressure vessels and in the fatigue laboratory was installed a machine for investigating the fatigue behaviour of thick-walled pipe containing circumferential butt welds under conditions of internal pulsating pressure. This machine had been designed in the mechanical engineering department of Bristol University and installed by arrangement with I.C.I.

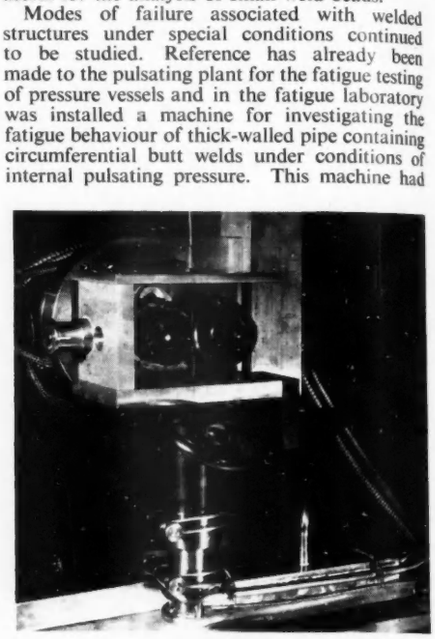


Fig. 4 Welding head designed for varying wire feed speeds in research into the characteristics of self-adjusting welding arcs. The argon gas shielding has been extended by means of a porous bronze diffuser to protect the weld head during cooling.

An interesting result arising from exploratory work with the object of improving the fatigue strength of details with discontinuous welds was the effect of rapid local heating applied in the area of the discontinuity. The greatly improved strength values obtained were thought to be due to the development of favourable compressive stress outside the heated zone.

BRITTLE FRACTURE

Work on brittle fracture, at present being mainly carried out with the aid of the 700 ton tensile test rig in which about 100 tests had already been performed on one-inch thick steel plate, will be assisted with a new 2,000 ton tensile test rig which was on view (Fig. 6). Designed by BWRA staff and constructed and donated by Babcock and Wilcox Limited, it will be used for tensile tests on welded and notched three-inch thick plate. In the course of these investigations an unexpected result had been obtained for mild steel welded wide plate specimens in which the sawcut notches had been extended by induced short fatigue cracks prior to fracture under a single application of load at a lower temperature. This specimen had an increased strength compared with a similar welded and notched specimen which had not been pulsated 80,000 times in tension to produce the fatigue cracks.

A belated exhibit not concerned with welding but with oxygen flame cutting was of interest since it indicated that with a preheat flame as used for steel, titanium could be cut five times as fast as steel of equivalent thickness using a lower oxygen pressure of 120 lb per sq. in. There were no harmful alloying or impurity effects observed.

NON-LINEAR FORCED VIBRATIONS OF CIRCULAR DISCS

An Experimental Investigation

By S. A. Tobias, D.SC., PH.D., M.A.*

The present investigation is concerned with the flexural vibrations of circular discs vibrating at large amplitudes. This problem does not appear to have been investigated before since all previous work confined itself to the case when the amplitudes are small. It will be seen that at large amplitudes the vibration becomes non-linear in the sense that the amplitude and phase jumps, well known from the theory of non-linear lumped constant systems, take place. Under certain conditions, at very large amplitudes, the disc ceases to vibrate with nodal diameters and its motion corresponds to a travelling wave which progresses with a periodically varying amplitude and speed.

The paper discusses non-linear forced vibrations of the 1/0, 0/0, 2/0 and 3/0 (nodal diameters/nodal circles) configurations of a disc which was clamped in the centre. The results presented form part of a comprehensive investigation of the linear and non-linear vibrations of rotating discs (Tobias, 1954,[2] Tobias and Arnold, 1957[3]).

LINEAR VIBRATIONS OF IMPERFECT DISCS

Before discussing the major topic of this paper, some little-known features of the linear vibrations of circular discs have to be summarised which are indispensable for the understanding of the non-linear vibrations.

When exciting a circular disc with a harmonically varying force the disc responds at certain frequencies with large amplitudes of vibration. These frequencies are known as resonance frequencies and they are approximately equal to the natural frequencies of the disc. The amplitude distribution of the disc when vibrating in one of its natural frequencies is called a mode of vibration. The modes of vibration are compounded of (1) nodal diameters ($s = 0, 1, 2$, etc.), (2) nodal circles ($c = 0, 1, 2$, etc.), and (3) a combination of both nodal diameters and nodal circles.

A diagrammatic picture of a disc vibrating with two nodal diameters (2/0) is shown in Fig. 1(*a*). Such a picture can be obtained by strewing sand on the vibrating surface which will tend to move towards the vicinity of the nodal diameters. The nodal diameters divide the disc into segments and disc particles in adjacent segments vibrate with opposite phase. The radial and co-axial amplitude variation is shown in Fig. 1(*b*).

As long as the disc is perfect, that is, its physical characteristics conform to perfect cylindrical symmetry, the angular position of the nodal diameters is indeterminate and depends only on the position of the exciting force. However, real discs can never attain this ideal of mathematical perfection even if they are manufactured with the utmost care, and discs used for experimental purposes are imperfect.

With the appearance of imperfections, the indeterminancy of the angular position of the nodal diameters is eliminated (Zenneck, 1899,[5] Tobias, 1951[1]), and the nodal diameters take up preferred positions. For each mode of vibration which contains at least one nodal diameter (and an arbitrary number of nodal circles) there will be two nodal positions and these constitute the so-called preferential configurations *p* and *q*. The preferential configurations possess slightly different natural frequencies and these, with the angular position of the nodes, are determined by the imperfections present. The preferential configurations are, in general, not symmetrically situated with respect to each other, as is indicated in Fig. 1(*c*) which gives a diagrammatic picture of the preferential configurations for a mode consisting of two nodal diameters. Fig. 2 shows the angular position of the preferential modes of the disc with which the experiments of the present paper were carried out for $s = 1, 2$ and 3 nodal diameters ($c = 0$). It should be added that the angular positions of the preferential configurations are determined by the law that their frequencies have either a minimum *p* or a maximum *q* in relation to any other position in which, by virtue of the cylindrical symmetry, vibration is possible.

Consider now the case of forced vibration due to a concentrated harmonic force, acting axially near the edge of the disc. When the disc is perfect the shape of the resonance curve and the resonance frequency will remain unchanged when the angular position of the force is varied. However, when the disc is imperfect the resonance curve of those modes which contain at least one nodal diameter will, in general, show two resonance peaks and the shape of the resonance curve will vary if the angular position of the exciting force is varied. This is due to the fact that if the exciting force acts between the preferential nodal diameters of the two configurations both will be excited simultaneously and each will be in resonance at its own natural frequency (*p* or *q*). When the vibration is linear, the two configurations vibrate independently of each other and each will go through the appropriate phase changes as the exciting frequency passes through the resonance range (Tobias and Arnold, 1957[3]). Resonance curves with one resonance frequency are obtained when the force coincides with a preferential nodal diameter of either configuration.

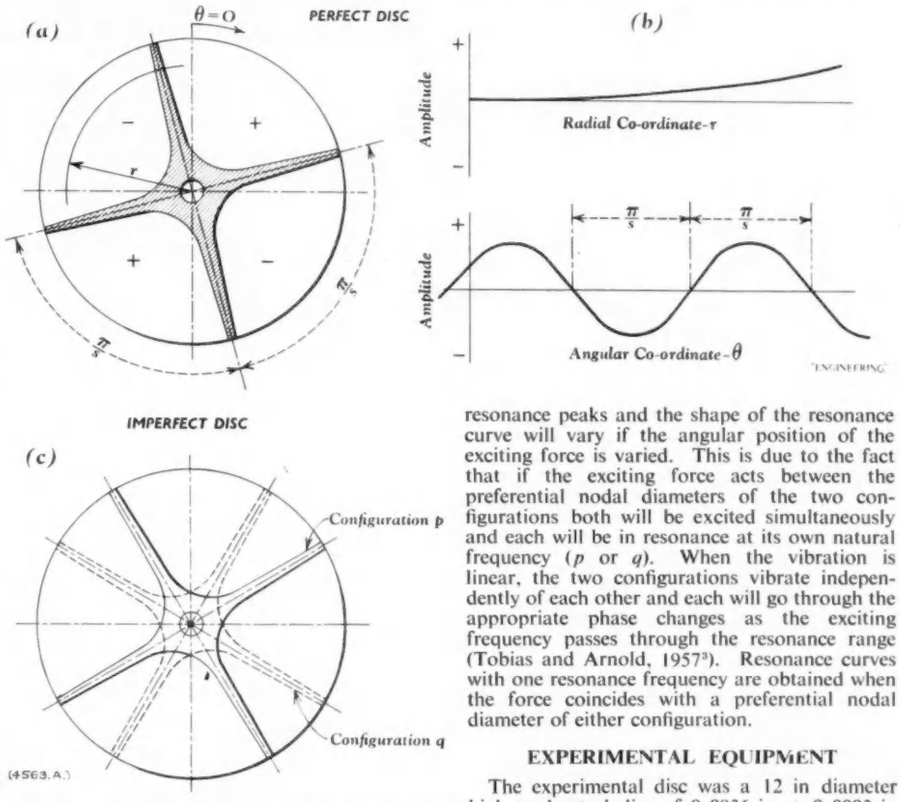


Fig. 1 Diagram of disc vibrating with two nodal diameters.

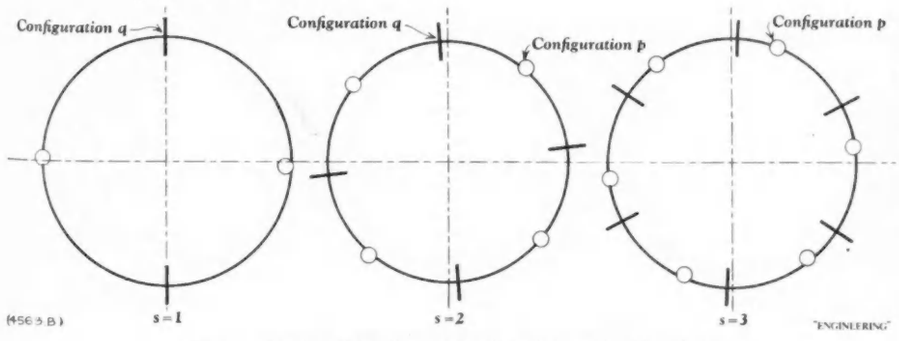


Fig. 2 Position of preferential nodes of experimental disc.

EXPERIMENTAL EQUIPMENT

The experimental disc was a 12 in diameter high-grade steel disc of 0·0936 in ± 0·0003 in thickness. Both sides of the disc were carefully ground. The disc was attached to a spindle through a ½ in hole in its centre and was clamped between two washers of 1 in outside diameter. It should be mentioned that before the present series of experiments was carried out the disc was used for the investigation of the vibration of rotating discs. In the course of that investigation it was exposed for considerable periods to severe straining by the centrifugal force and, as a result, its vibrational characteristics changed (Tobias and Arnold, 1957[3]).

Electromagnetic excitation of the vibration was employed. The exciting frequency was generated by a variable frequency oscillator, amplified by two 20-watt amplifiers and fed into a large electromagnet. The effective surface of the magnet was 1½ in × ⅞ in. To ensure an approximately sinusoidal force variation the exciting current was superimposed on an

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Continuing Research and Development

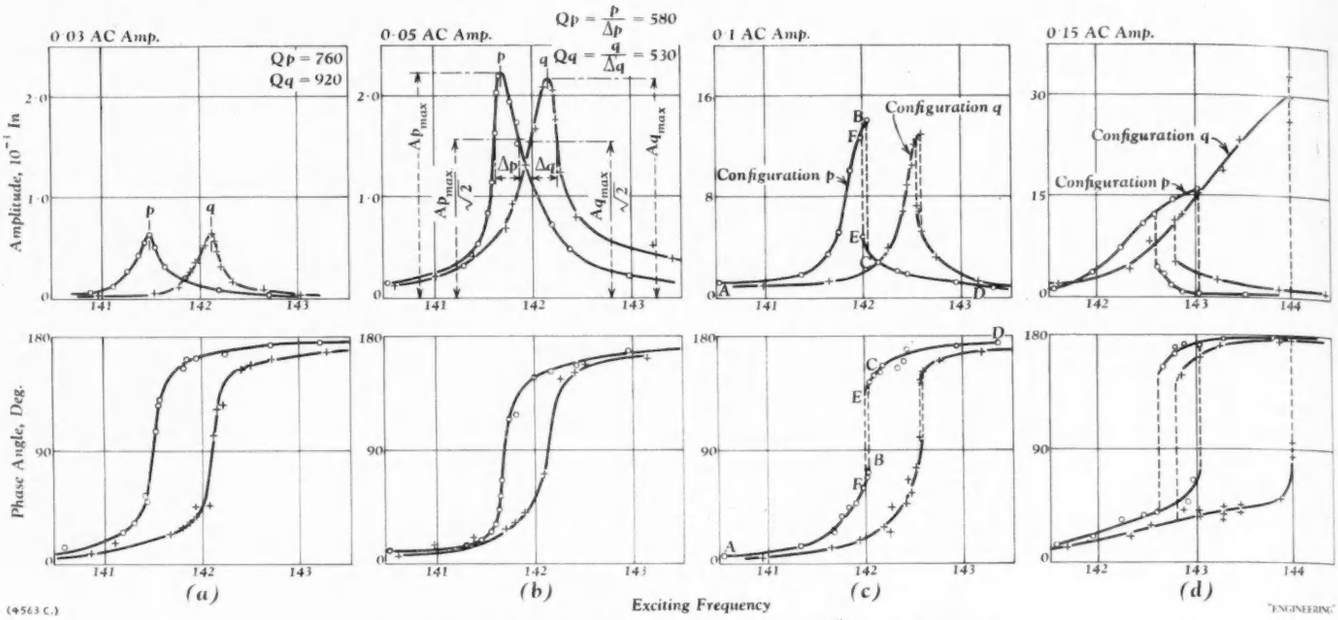

Fig. 3 Linear and non-linear resonance and phase curves of 2/0 mode.

appropriate direct-current level. The vibrations were measured by the capacitive method, that is, by converting minute capacitance variations between a ½ in diameter pick-up plate and the earthed disc into voltage variations. Frequency measurements were carried out with an electronic counter which counted the number of cycles over an accurately controlled time interval (46 sec.). The resolution of this frequency meter was ± 0·02 cycle per sec. over the whole frequency range. Phase measurements were made with an electronic phase meter. A more detailed account of the experimental equipment has been published (Tobias and Arnold, 1957[3]).

NON-LINEAR RESONANCE AND PHASE CURVES OF THE 2/0 CONFIGURATION

To begin with, the mode consisting of two nodal diameters and no nodal circles will be discussed since it was explored in greatest detail. Its resonance and phase curves, for successively increasing energy input, that is, amplitude of vibration, are shown in Figs. 3 and 4. These curves were obtained by the following procedure: after determining the position of the preferential nodes (Fig. 2) the exciting magnet was placed to face a nodal diameter of configuration q (Fig. 5(*a*)). In this position configuration p only should be excited since q cannot be excited by a force acting at one of its nodes. By measuring the forced amplitudes at a diameter which is 90 deg. with respect to the force the resonance curve of configuration p is determined. The resonance curve of configuration q was measured by an analogous procedure. For all curves shown in Figs. 3 and 4 the magnet airgap (½ in) remained unchanged and greater amplitudes were obtained by increasing the amplifier output. The alternating-current input is indicated in the figures.

In the case of Figs. 3(*a*) and (*b*) the vibration was clearly linear, although the resonance frequencies show a slight dependency on the resonance amplitude. With increasing amplitude the preferential frequencies increase but not at the same rate, so that $(q - p)$ decreases. From the resonance curves the "dynamic amplification factor Q" was determined:

$$Q_p = \left(\frac{p}{\Delta p}\right) \quad \text{and} \quad Q_q = \left(\frac{q}{\Delta q}\right)$$

where p and q are the preferential frequencies and Δp and Δq is the width of the resonance curve at $\frac{1}{\sqrt{2}}$ the resonance amplitude. For increasing amplitudes, Q_p and Q_q decreases that is, damping increases. The damping of the two configurations is unequal.

Resonance curves of the type of Fig. 3(*a*) and (*b*) were obtained for amplitudes smaller than about 0·005 in. Beyond this limit curves of the type shown on Figs. 3(*c*) and (*d*) and Fig. 4 were observed. In Fig. 3(*c*) the non-linear characteristic of the vibration is already clearly visible. Considering configuration p first, as

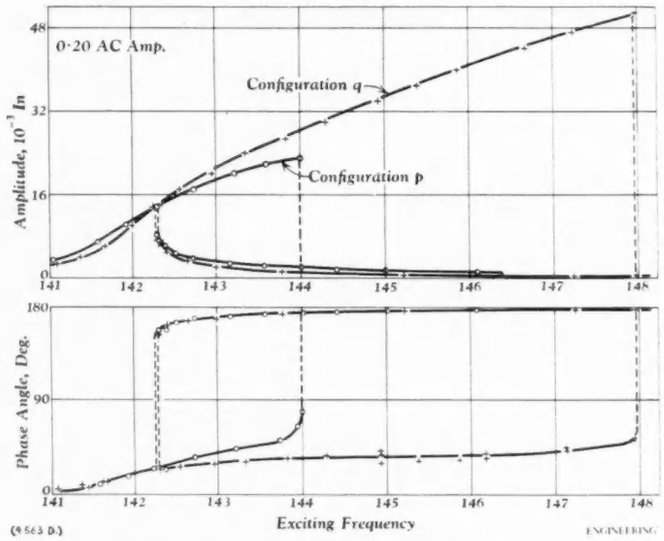

Fig. 4 Non-linear resonance and phase curve of 2/0 mode.

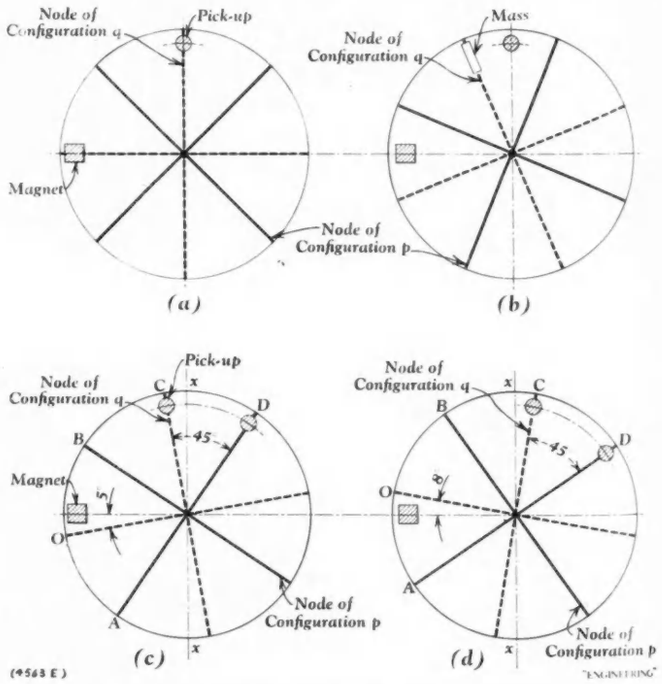

Fig. 5 Relative position of magnet, pick-up and nodal diameters.

the frequency is increased the amplitudes of vibration are given by the ordinates of the curve A B. When point B is reached the vibration collapses, that is, the amplitude drops to point C. A further increase in frequency results in an amplitude variation along the curve C D. By decreasing the frequency from D the amplitude varies along the curve D C E. Passing through C, at E it jumps to point F and for a further decrease varies along the curve F A. In a similar way, for increasing frequencies the phase angle varies along A B, jumps at B to C and continues on the curve C D. By decreasing the frequency the phase variation is given by the curve D C E, suddenly dropping at E to F and continuing from F to A. The amplitude and phase variation of configuration q is intrinsically the same, as is obvious from the figure.

In the case described by Fig. 3 (*c*) the vibrations of the two configurations are still independent of each other, i.e., they can be excited separately. If the input energy is further increased (Fig. 3 (*d*) and Fig 4), after a certain amplitude has been reached, this ceases to be true and the two configurations become coupled. The peculiarity of this coupling is that it is unsymmetrical, i.e., whenever configuration p is excited configuration q is also excited although with smaller amplitudes and there are no real nodes on the disc. However, configuration q can be excited separately without configuration p being set into motion and the disc vibrates with clearly defined nodes.

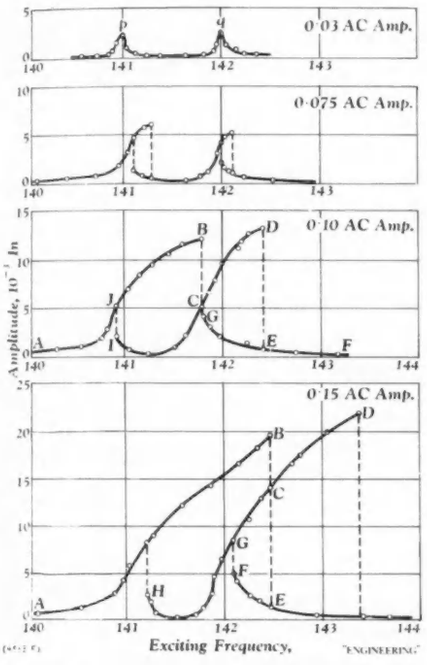

Fig. 6 Simultaneous excitation of both preferential configurations in the linear and non-linear range.

In both Fig. 3 (*d*) and Fig. 4 the collapse amplitude of configuration p is considerably smaller than that of configuration q. If configuration p only were excited after a certain frequency (about 142 cycles per sec. in Fig. 4) its nodes started to vibrate with small amplitudes. Since the nodes of configuration p are anti-nodes of q, this means that both configurations were excited. As the frequency was increased the amplitudes of both the anti-nodes and the nodes of configuration p increased. In the case of Fig. 3 (*d*) the amplitudes of the anti-nodes were always greater and there were relative nodes on the disc. At higher energy inputs (for instance, Fig. 4) the relative nodes increased their amplitudes more rapidly than the anti-nodes and near the collapse point every point of the disc circumference appeared to vibrate with equal amplitudes. Viewed in the light of a stroboscope the motion corresponded to a beating travelling wave which, with increasing frequency, developed into a uniform travelling wave. Similar observations were made at even greater energy inputs (up to 0·45 A.C. ampere) when this effect was more clearly visible. On the other hand, configuration q could be excited on its own up to even greater amplitudes.*

While measuring the resonance curves of Fig. 3 (*d*) for configuration p a small angular oscillation of the relative nodes was observed above and below 142·7 cycles per sec. As the exciting frequency approached this value these oscillations were first small and rapid, slowed down and became zero at about 142·7 cycles per sec. and reappeared again just before the collapse point. When exciting configuration q a similar behaviour was observed, commencing at about 143·25 cycles per sec. This latter nodal oscillation was accompanied by a phase and amplitude oscillation which became more violent as the collapse point was being approached. The limits between which the amplitude was oscillating just before the collapse point is indicated in the figure. Identical observations for configuration q were made in the case of Fig. 4 (from about 144·3 cycles per sec. onwards) and also at higher energy inputs. Just before the collapse point the angular amplitude of the nodal oscillations was $\pm$ 6 deg.

It was pointed out that if the exciting force is acting between the nodal diameters of the preferential modes both configurations are excited simultaneously and a resonance curve with two peaks will be measured. For medium amplitudes this is also true in the case of non-linear vibrations, as will be shown with Fig. 6. For the measurement of these curves (and also those of Fig. 7) the exciting magnet and the pick-up were placed as shown in Fig. 5 (*b*). To investigate the effect of a small artificial imperfection on the vibration, a square steel rod (0·156 in. × 0·631 in. × 0·125 in.) of 1·5 gramme weight was attached radially to an anti-node of configuration p. Clearly, an anti-node of p being a node of q, in the linear range this imperfection should not affect q, but should lower p. As can be seen from the top figure of Fig. 6 (0·03 A.C. ampere) q was only very slightly lowered, probably owing to the finite height of the imperfection. By increasing the energy input to 0·075 A.C. ampere the second figure of Fig. 6 was obtained. At this stage, in spite of the pronounced non-linearity, the coupling effect between the two configurations appeared to be negligible. After the amplitude has reached the collapse point of the first resonance curve, it drops to the lower line and continues towards the second collapse point. At an input of 0·10 A.C. ampere, for increasing frequency the amplitude varied along the curve AB and only towards the end of this line were small amplitudes of the nodes observed. At the collapse point B the amplitude dropped to C and continued along CD. Decreasing the frequency from F an amplitude jump occurred at G to C and the subsequent variation was along the curve CI, ending in a second jump at I to J. Thus the collapse of configuration p did not result in the collapse of configuration q. Increasing the input current to 0·15 A.C. ampere, in some experiments the amplitude dropped from the collapse point B to point C and in others to point E. If the input energy is still further increased the collapse of p is inevitably followed by the collapse of q. A resonance curve of this type is shown in Fig. 7 (*a*) (0·3 A.C. ampere).

Increasing the frequency from point A, to begin with, nodes are observed which start to vibrate with slowly growing amplitudes as the frequency passes through point J. From about 144 cycles per sec. onwards a uniform travelling wave was observed. At point B the amplitudes drop to C and by decreasing the frequency E is reached where a jump to F is encountered. By increasing the frequency again the amplitudes vary along curve FG and the disc vibrates with sharply defined nodes. Approaching G an amplitude and phase oscillation occurs and finally the amplitude drops from G to H.

When, after the amplitude jump from E to F, the frequency is decreased at point I another jump occurs to point J. The second pass along curve J B differs from the first. The nodes start to vibrate only after the frequency has passed the ordinate passing through the F E points (142·24 cycles per sec.) and after that they attain an appreciable amplitude rather suddenly. If the input is further increased (0·4 A.C. ampere, Fig. 7(*b*)) only one resonance curve is obtained. This does not mean that the resonance curve of configuration q does not exist; it can be obtained by exciting q separately.

* At great energy inputs (0·3 to 0·45 A.C. ampere) it was sometimes difficult to excite configuration q on its own. After an initial stage in which the disc vibrated with absolute nodes, the nodes started to vibrate and the presence of a travelling wave was noted. However, by commencing with small energy inputs and increasing it after appreciable amplitudes were reached, it was always possible to obtain configuration q on its own.

THE NON-LINEAR TRAVELLING WAVE EFFECT

Preliminary experiments of the non-linear travelling wave showed that its direction of progression is dependent on the position of the exciting force relative to the preferential nodes. In successive tests, in which the angular position

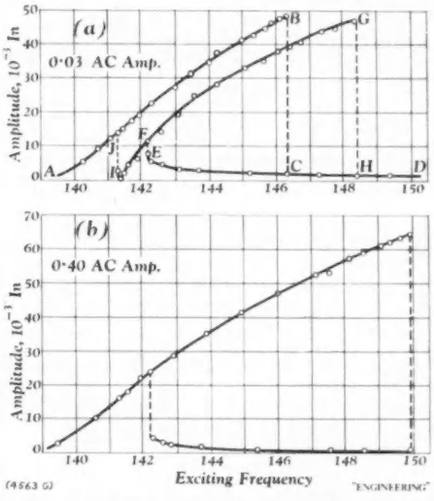

Fig. 7 Simultaneous excitation of both preferential configurations in the non-linear range at large amplitudes.

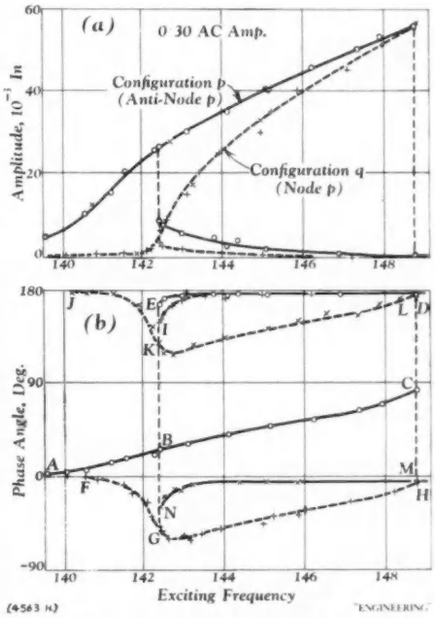

Fig. 8 Resonance and phase curve of 2/0 mode showing amplitude and phasing conditions of non-linear travelling wave.

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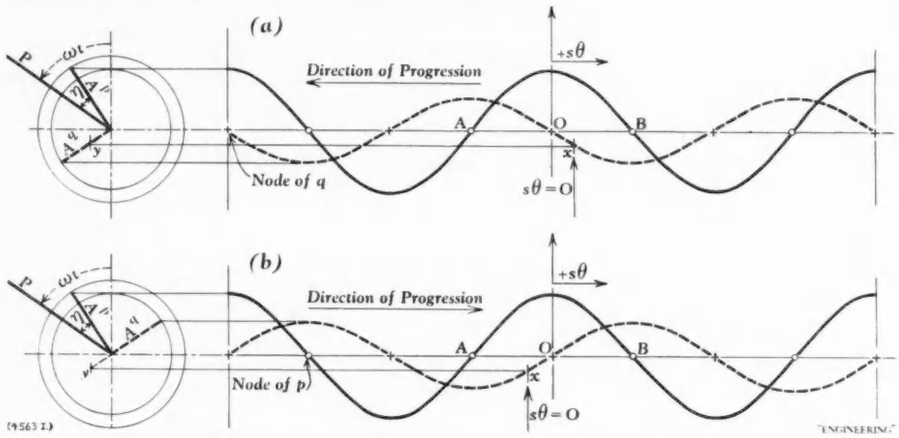


Fig. 9 Explanatory diagram for non-linear travelling wave.

of the force was varied in steps, it was ascertained that whenever the force was moved from one side of a preferential node to the other, the direction of progression of the wave changed. As was already mentioned, when the force is acting on a node of configuration p or very near to it (within $\pm$ 5 deg.) the disc vibrates with absolute nodes. What happens when the force is acting exactly on a node of configuration q was impossible to observe since the magnetic force was distributed over a finite area. Owing to this reason the amplitude and phasing conditions of the travelling wave were investigated by off-setting the force by a small angle (5 deg.) to either side of a node of q, as shown in Figs. 5(*c*) and (*d*). In both tests the pick-up was first placed at an anti-node of configuration p to measure the amplitude and phase curve of that configuration. The corresponding curves belonging to configuration q were determined by turning the pick-up by 45 deg. to face a node of p (anti-node of q). The results of these experiments are shown in Figs. 8(*a*) and (*b*).

Consider the case of Fig. 5(*c*). The amplitude variation of an anti-node of p (node of q) is presented in Fig. 8(*a*) (full curve) and the measured points are indicated by circles. The phase curve of this configuration is shown in Fig. 8(*b*) (curves A B C and D E) and it can be seen that it does not differ from those already shown (*cf.* for instance, Fig. 3). Curve A B C has been drawn in such a way that at small amplitudes it approaches the 0 deg. ordinate. Reference to Fig. 5(*c*) shows that the force and pick-up being on opposite sides of a nodal diameter (diameter B in Fig. 5(*c*)) at very small amplitudes the force and the measured displacements must be 180 deg. out of phase. Thus, with respect to the force the ordinate 0 deg. represents the phase angle 180 deg. The notation of Fig. 8(*b*) has been used to keep in line with the previous phase diagrams. All it implies in the present case is that the force exerted by the magnet is substituted by an imaginary force which is 180 deg. out of phase and which lies in the $x - x$ diameter of Figs. 5(*c*) and (*d*) between points C and D, and B and C, respectively. All phase curves will be referred to this imaginary force.

The amplitudes of a node of configuration p (anti-node of q) for the case of Fig. 5(*c*) is shown by the dotted line of Fig. 8(*a*) (points +). Below 142 cycles per sec. configuration q was excited with small amplitude. This is not surprising since the force acted very near to a node of q but did not coincide with it. Above 142 cycles per sec. the amplitudes of q increase rapidly and visual observation showed the presence of a developing beating travelling wave. From about 145 cycles per sec. onwards all points of the disc appeared to vibrate with equal amplitudes. However, it can be seen from Fig. 8(*a*) that the amplitudes of p and q were equal only at the collapse point. After the collapse, by decreasing the frequency the amplitudes of q varied along the lower branch of Fig. 8(*a*) (dotted line). The jump frequency of both configurations coincided.

The phase variation of configuration q (Fig. 8(*b*), curves F G H and D I) is of interest. Initially, q was in phase with the imaginary force (or 180 deg. out of phase with the magnetic force) as it should be. As the exciting frequency approached 142 cycles per sec. q gained phase with respect to the imaginary force and shortly after point G it was $\sim$ 90 deg. ahead of configuration p. At point H the phase jumps to point D and the deviation between the phase of p and q on the lower branch of the resonance curve becomes appreciable only near to point I, from which the phase of q drops to G.

Consider now the case of Fig. 5(*d*). The resonance curves of the two configurations were almost identical with those of the previous case and therefore only a few representative points denoted by $\times$ have been drawn in Fig. 8(*a*). In a similar way, the phase curves of configuration p remained unchanged, as was to be expected. Below 140 cycles per sec. configuration q (node of p) was 180 deg. out of phase with the imaginary force. This is due to the node of q which is between pick-up and force (C in Fig. 5(*d*)) and which results in a phase reversal. Increasing the frequency the curve J K L is obtained for the phase of configuration q with respect to the imaginary force. This curve is almost identical with the curve F G H but is displaced by 180 deg. Thus, in the case of Fig. 5(*d*) configuration q lags behind configuration p and at large amplitudes the phase difference is again $\sim$90 deg. When the vibration has reached point L the phase jumps 180 deg. and to draw in this curve Fig. 8(*b*) should be extended upwards by 180 deg. However, since (180 deg. $-$ Δ deg.) + 180 deg. = 0 deg. $-$ Δ deg. this curve is represented by the M N curve. Decreasing the frequency from the collapse point the amplitude varies along the lower branch of Fig. 8(*a*) (dotted line), the phase along M N and having reached N it jumps to K.

Once the phase relationship between the two configurations is known it is easy to establish with elementary considerations the law which determines the direction of progression of the non-linear travelling wave. Figs. 9 (*a*) and (*b*) represents part of the disc circumference on which alternatingly the nodes of configuration p (○) and configuration q (+) are situated. The origin of the angular co-ordinate $s\theta$ is placed at a node of configuration q (point O). It is assumed that the force $P\cos\omega t$ acts between points O and B. The amplitudes of configuration p can be expressed as

$$A^p \cos s\,\theta \,.\, \cos(\omega t - \eta)$$

where η is the phase lag of the configuration with respect to the force. According to the previous experimental results, for this position of the force configuration q is ahead of p by 90 deg. and so the amplitudes of q can be expressed as

$$A^q \sin s\,\theta \cos(\omega t - \eta + 90 \text{ deg.}) = -A^p \sin s\,\theta \sin(\omega t - \eta).$$

Assuming $A^p = A^q = A$ the superposition of the preferential configurations results in the travelling

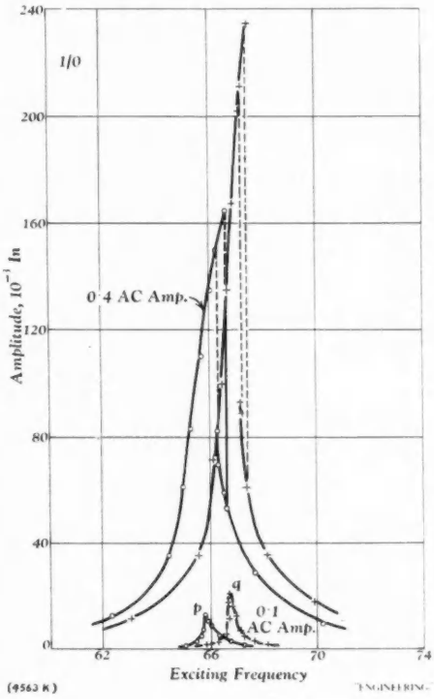
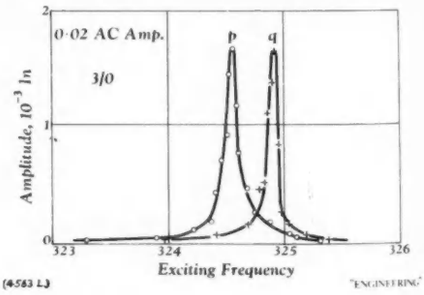
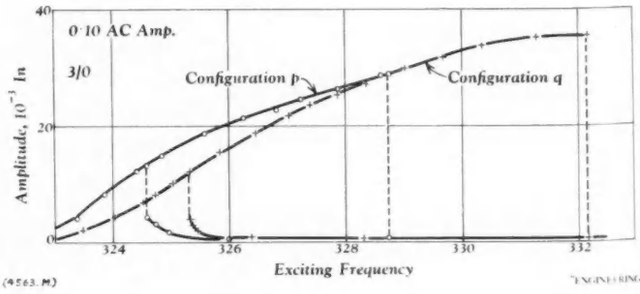


Fig. 10 (left) Linear and non-linear resonance curves of 1/0 mode.

Fig. 11 (right) Linear resonance curves of 3/0 mode.

Fig. 12 (below) Non-linear resonance curves of 3/0 mode.





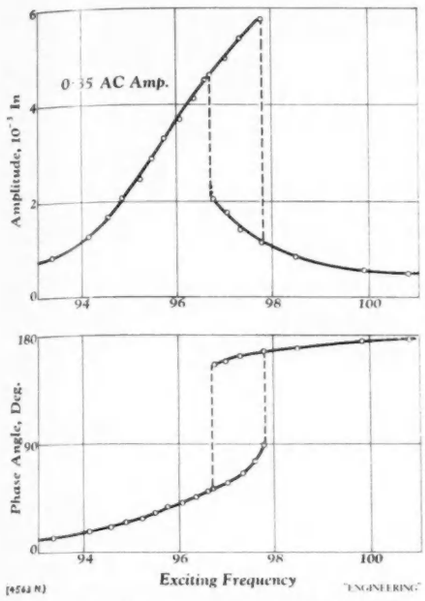


Fig. 13 Non-linear resonance curve of 0/0 mode.

wave A cos $[s\theta + (\omega t - \eta)]$. This wave travels in the $-s\theta$ direction with $\frac{\omega}{s}$ speed, i.e., it progresses from a node of p (point B), through the force, towards a node of q (point O). In a similar way can be treated the case when the force acts between point O and A, the only difference being that in that case the wave has the form

$$A \cos [s\theta - (\omega t - \eta)],$$

that is, it travels in the $+s\theta$ direction, but the afore-stated rule applies again. Thus the law which determines the speed direction of non-linear travelling waves can be stated as follows: *The non-linear travelling wave progresses from the force towards the nearest anti-node of configuration p (node of q).* This law is a direct consequence of a relation which is not obvious from Fig. 9 (*a*) and (*b*). Although in the case of Fig. 9 (*a*) configuration q is ahead and in the case of Fig. 9 (*b*) it lags behind configuration p, at the point where the force acts the phase relationship between a particle of the disc and the force is identical in both cases. The particle of the disc which faces the force performs two vibrations, corresponding to configurations p and q. The vibration due to p lags behind the force and this is clear from Fig. 9 (*a*) and (*b*). What is not obvious from the figure is that in both cases the vibration due to q is ahead of the force. This has been indicated in Fig. 9 (*b*) by the x-y line. That at the force the phase relationship is the same in both cases can also be seen from Fig. 8 (*b*). The reason for the opposed phasing between the two configurations in Fig. 9 (*a*) and (*b*) is simply due to the fact that in the first case the force acts at $+s\theta$ and in the second at $-s\theta$.

Once the non-linear travelling wave has established itself, its direction of progression remains unchanged if the exciting force is moved from one side of a nodal diameter to the other. If in the presence of a travelling wave the disc is rotated very slowly, as soon as an anti-node of configuration q (node of p) comes within about 5 deg. of the force, configuration p quickly decreases its amplitudes and ceases to vibrate. However, in the majority of cases, configuration q continues to oscillate with clearly visible nodes. In some cases both configurations continued to vibrate, but the motion was neither a travelling wave nor a fixed vibration since the nodal diameters performed an oscillatory motion. Somewhat higher speeds of rotation (about 1 to 2 rev. per second) do not appear to affect the travelling wave to an appreciable extent and it is also immaterial whether the wave progresses in the direction of the disc rotation or is opposed to it.

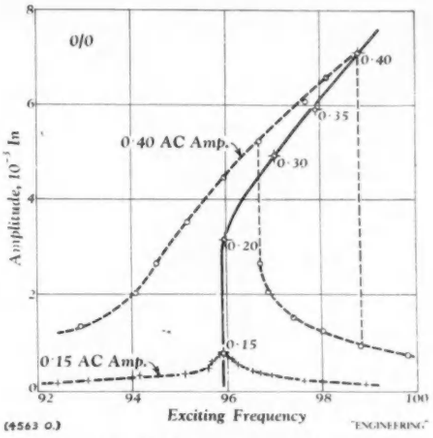


Fig. 14. Collapse locus of 0/0 mode.

However, as the speed of disc rotation is increased the travelling wave ultimately collapses.

The most striking feature of the non-linear travelling wave effect is its existence when the force acts on a node of configuration q. In this case the energy needed for the excitation of q cannot be derived directly from the force. Although in practice a small amount of energy is always fed into q owing to the finite distribution of the force, this energy cannot be sufficient to maintain amplitudes of equal magnitude with those of configuration p. The only feasible explanation is that q derives its energy from p by means of parametric excitation. That this is in fact the case can be seen from a mathematical analysis of the non-linear travelling wave effect published elsewhere (Tobias, 1957[4]). It is shown that owing to the stretching of the middle surface at large amplitudes, the "spring constant" of configuration q ceases to be constant but fluctuates periodically around an average value. As long as the amplitudes of configuration p remain below a certain critical value, configuration q remains stable and the disc vibrates with fixed nodal diameters. However, above a certain amplitude value of p, configuration q becomes unstable and commences to oscillate as well. In this case the amplitude ratio of the two configurations is determinate and their phase relationship is $\sim \pm 90$ deg. Which of the two configurations is leading (i.e., whether $+90$ deg. or -90 deg.) depends solely on the initial phasing at small amplitudes which grows to $\sim \pm 90$ deg. The initial phasing, in turn, is determined by the position of the exciting force with respect to the nodal diameters, as already explained. It is also shown that configuration p is stable for all amplitude values of configuration q and so the coupling between the two configurations is indeed unsymmetrical.

NON-LINEAR VIBRATIONS OF THE 1/0, 3/0 AND 0/0 MODES

The non-linear vibrations of all those modes which contain nodal diameters have intrinsically the same characteristics as the two nodal diameters mode. As the number of nodal diameters increases, the effect of non-linearity becomes appreciable at diminishing amplitudes.

Linear and non-linear resonance curves of the 1/0 mode are shown in Fig. 10. The vibration was linear for amplitudes up to $\sim 0{\cdot}090$ in. When exciting configuration p at very large amplitudes its nodes vibrated with small amplitudes and a beating travelling wave was observed. When the force acted half-way between the preferential nodes, the disc circumference vibrated with uniform amplitudes and in the light of the stroboscope a uniform travelling wave became visible. The rule which determined the direction of progression of this wave was identical with that which is valid for the 2/0 configuration.

Fig. 11 shows a linear resonance curve of the 3/0 mode. The vibration was linear up to amplitudes of $\sim 0{\cdot}002$ in. To obtain non-linear resonance curves the magnet-disc air gap had to be reduced to 0·15 in since the output of the amplifier fell rapidly above 200 cycles per sec. A fully developed non-linear resonance curve of this configuration is presented in Fig. 12. When configuration p was excited on its own from about 325·5 cycles per sec. onwards, the nodes vibrated with rapidly increasing amplitudes and above 327·5 cycles per sec. a uniform travelling wave was present. Configuration q could be excited with absolute nodes up to an energy input of 0·15 AC ampere, resulting in a collapse amplitude of 0·05 in. If the input energy was further increased violent amplitude and phase oscillations were observed at large amplitudes which resulted either in a complete collapse of the vibration or in its sudden transformation into a travelling wave. The amplitude of this travelling wave could be increased by increasing the exciting frequency until finally it collapsed.

When the disc vibrates in the 0/0 configuration there are no nodal diameters or circles and the disc vibrates in the shape of an "umbrella." Owing to the absence of nodal diameters there is, of course, only one resonance frequency. A typical non-linear resonance and phase curve is shown in Fig. 13. Two further resonance curves are presented in Fig. 14 and these will be

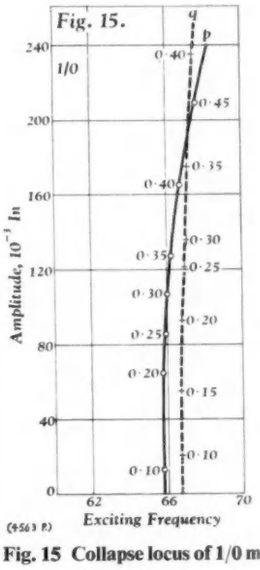


Fig. 15 Collapse locus of 1/0 mode.

Fig. 16 Collapse locus of 2/0 mode.

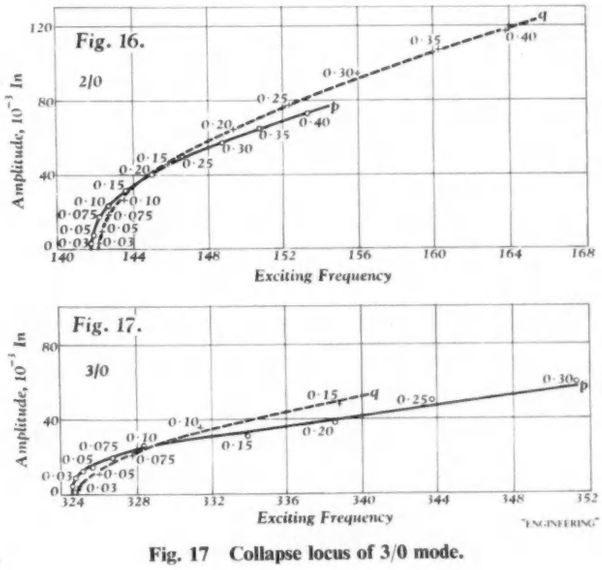


Fig. 17 Collapse locus of 3/0 mode.

Continuing Research and Development

discussed in the following section. The vibrations of the 0/0 configuration were linear up to amplitudes smaller than 0·025 in.

COLLAPSE LOCUS CURVES

Certain important features of the non-linear vibrations of circular discs are conveniently discussed with the aid of the collapse locus curves. These are obtained by plotting the collapse amplitude as a function of the collapse frequency for increasing energy inputs. In the linear range, the resonance amplitude is used, instead of the collapse amplitude. As a simple illustration Fig. 14 is given which, as has already been mentioned, refers to the 0/0 configuration. The resonance curve obtained with 0·15 AC ampere input belongs to the linear range. Its resonance amplitude is denoted by 0·15 in the figure. By increasing the input to 0·20 AC ampere the resonance amplitude denoted by "0·20" is obtained. Further increases of input yield non-linear resonance curves, the collapse points of which are denoted in the figure by 0·30, 0·35 and 0·40. In all cases the numbers signify the input current with which the particular collapse or resonance point was obtained. The curve through these points is the collapse locus.

The case is slightly more involved for those modes which contain nodal diameters owing to the fact that each preferential configuration possesses its own collapse locus and so two curves will be obtained for each mode. The collapse locus of the 1/0, 2/0 and 3/0 modes is shown in Figs. 15, 16 and 17, respectively. These curves were determined by separately exciting the two configurations in the usual way, that is, by placing the exciting force at a node of configuration q and p, respectively. Similarly to Fig. 14, the magnet input current corresponding to each measured point is written in the figures.

From these figures the following general characteristics of the collapse locus can be read. Clearly, the curves intersect the frequency axis at 90 deg. since for very small amplitudes the resonance frequency does not depend on the resonance amplitude. For the same exciting force (exciting current in AC amperes), the collapse amplitude of configuration q is greater than that of configuration p and the difference between them increases as the amplitudes increase. The reason for this lies in the fact that configuration q can be excited on its own and consequently the whole energy input is used for its excitation. On the other hand, at large amplitudes the excitation of configuration p is accompanied by the parametric excitation of q and as a result the energy is distributed between two configurations. It follows that the collapse locus of p and q have not the same significance since the former refers to a non-linear travelling wave and the latter to a fixed vibration. It is significant that the collapse locus of the two configurations intersect in all cases, thus the effect of non-linearity is greater on the travelling wave than on the fixed vibration.

The importance of the collapse locus curves lies in the fact that they describe the transient conditions following the collapse of the forced vibration. As already mentioned, at the collapse point the amplitude drops to the lower branch of the resonance curve. This amplitude drop is not instantaneous but takes a finite time interval. Condensed photographic records taken of the transient conditions following collapse are shown in Figs. 18 (*a*) and (*b*). Fig 18 (*a*) corresponds to configuration q and Fig. 18 (*b*) to configuration p, or more precisely to the non-linear travelling wave measured at an anti-node of p. Disregarding for the time being the amplitude modulation of these traces,* their appearance is essentially similar to that of a free damped vibration. From extended traces of a similar kind to Figs. 18 (*a*) and (*b*) it was ascertained that at the point of collapse the non-linear

* The lack of symmetry in the traces of Figs. 18 (*a*) and (*b*) is due to the non-linear distortion of the amplitude measuring device.

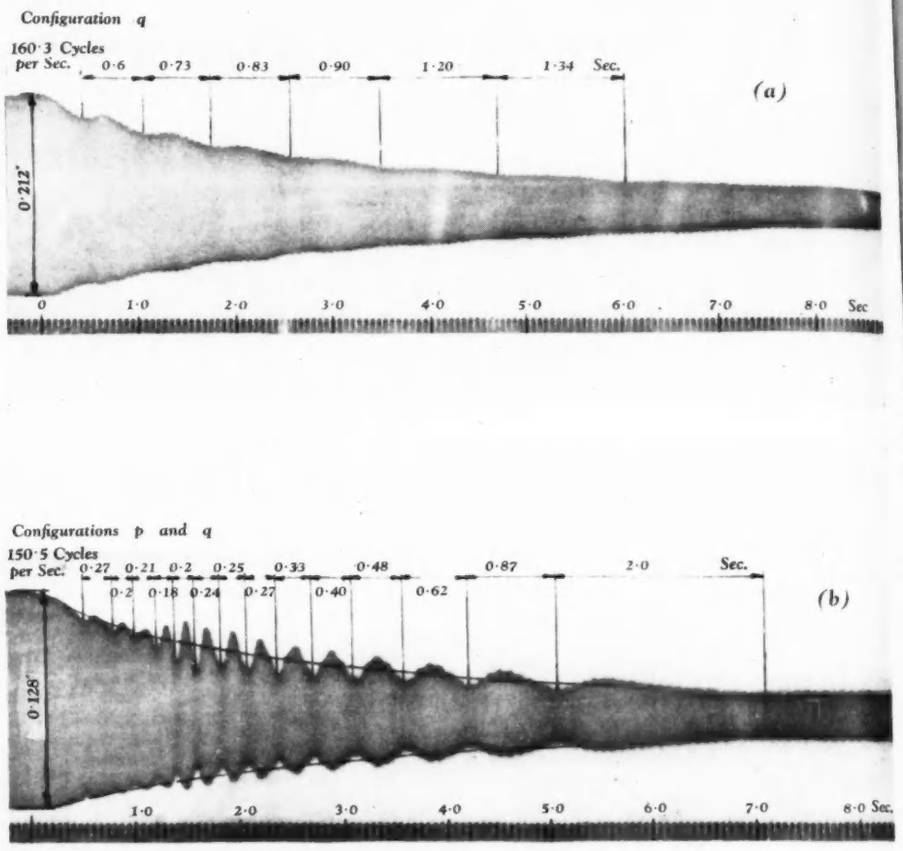


Fig. 18 Transient conditions following collapse of 2/0 mode.

forced vibration is transformed in a free damped vibration, the frequency of which decreases as its amplitudes subside. The relationship between the amplitudes and the frequency is given by the collapse locus curves.

A distinction has to be drawn, of course, between the collapse of configuration q and the collapse of the non-linear travelling wave. In the first case the disc vibrates with fixed nodal diameters and the position of these alters only slightly as the amplitudes subside. This may be the explanation of the small amplitude beating visible in trace Fig. 18 (*a*). In the second case a rapid nodal oscillation was observed shortly after the initial stage and it appears that this was connected with the amplitude beating. The causes of the amplitude beating (and nodal oscillations) are not clear. They may lie in the fact that the amplitudes and phasing of the two configurations are rigidly connected but the inherent damping of the two modes is bound to be slightly different.

It should be remembered that during the collapse process the exciting force was still acting. It appears that as long as the vibration is non-linear its effect is small. However, when the amplitudes have become small the frequency of the exciting force made its appearance in the free vibration traces and as soon as the free vibrations subsided the disc was vibrating with an amplitude corresponding to the lower branch of the resonance curve and the collapse frequency.

CONCLUSIONS

The primary cause of the non-linearity of the vibration of discs at large amplitudes appears to lie in the stretching of the middle surface. This effect is sufficient to explain the non-symmetrical coupling between the two configurations. However, in addition, it is likely that the stress dependency of Young's modulus must also be taken into consideration. Since Young's modulus decreases as the stresses increase, the two effects partly compensate each other and so the non-linearity is smaller than would be expected by considering only the stretching of the middle surface.

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Book Reviews

PROTAGONIST OF TECHNICAL SCHOOLS

Henry Edward Armstrong, 1848-1937. By J. VARGAS EYRE. *Butterworths Scientific Publications, 4 and 5 Bell Yard, London, W.C.2.* (30*s.*)

High up on the wall in the entrance hall of the City and Guilds (Engineering) College, soon to be pulled down to make way for more modern buildings which he would have envied, there rests the bust of a bearded Victorian figure who was one of the four original professors of the College when it received its first student in 1885. Perhaps because he was Professor of Chemistry in a Technical College, perhaps because he was more interested in scientific disputation and education than in research achievement, he has had to await the publication of this biography to receive the credit which is due to him. In fact he made a substantial contribution, much ahead of its time, to thinking on technical education and the teaching of science in schools.

Henry Armstrong was born at the turn of the century when the growth of science and industry in Germany was beginning to threaten the dominant position so far held by this country. Educated under Hofmann and Frankland at the Royal College of Chemistry, and later at Leipzig, he returned to England to do battle against the didactic methods then employed for the teaching of science and in support of the method of experiment and deduction, particularly in the training of those who were going into industry.

His first post was as lecturer in chemistry at the London Institution and at St. Bartholomew's Hospital Medical School. The Institution was a typical product of its age, combining evening lectures on the application of science to industry with social activities. In 1879 he was appointed lecturer in chemistry at the City and Guilds Institute, with W. C. Ayrton lecturer in Physics. The Institute was the first reluctant outcome of the pressure brought by Gladstone on the Guilds of London, after the Great Exhibition of 1851, to shame them into using their wealth for industrial education at a time when there was no public provision. It was soon followed by the Finsbury Technical College where day courses were introduced in 1883. The turning of the original Institute from a trade school into a technical college was largely due to the influence of Armstrong who had very strong views on the kind of courses which the future generation of industrialists was going to need. He believed in a broad education, including engineering and practical work for chemists and chemistry with laboratory work for engineers. When he moved with Ayrton to the Central Technical College in South Kensington in 1885, he tried to introduce a four-year course in chemical engineering; but the governors of the college insisted on a three-year course and the first prospectus offered a diploma in chemical engineering in three years, the first of its kind in this country.

Originally the Central College offered courses in chemistry and physics, but gradually these became ancillary to mechanical and electrical engineering and even Armstrong's idea of a course in chemistry, specially designed for engineers, was finally turned down when the college became part of the Imperial College of Science and Technology, and in 1911 instruction in chemistry was transferred to the Royal College of Science. In the arguments that led to the amalgamation of the three colleges Armstrong played his full part and no doubt made many enemies. Nevertheless it is surprising to learn that he was dismissed, without pension, although room was found for him in the RCS to continue his research.

Armstrong was typical of the argumentative and assertive personalities with which the late Victorian era seemed to abound and, although a stickler for accuracy in experiment, he does not seem to have been so careful in discussion. In his conflicts with the administrators of the College, who seem sometimes to have behaved with the pettiness of a minor local authority, the rights were no doubt not all on one side. Although only 66 when the first war with Germany broke out, he was not used in any official capacity and it is a pity that the reasons for this are glossed over, although they would have been of greater interest than some of the rather undistinguished descriptions of family life and travels.

Apart from the intrinsic merits of its subject, this book is useful in recalling the atmosphere in which technical education grew up in this country and the conflicts which took place between those, like Armstrong, who realised the need for a scientific basis to engineering education and those who thought only in practical terms. At that time little science was taught in the schools and Armstrong, in face of considerable scepticism, continued to press for school laboratories in which the child would be led along the path of inquiry by natural inquisitiveness. This method he practised with his own children; for instance by getting them to measure the difference between the weight of stones in air and in water.

Many of his battles have now been won; some of those he lost have led to results of which he would have approved; but if he were alive to-day, he would still find administrative obscurantism frustrating the development of technical education in many parts of the Kingdom.

NEW BOOKS

Hydraulics and Fluid Mechanics. By E. H. LEWITT. *Sir Isaac Pitman and Sons Limited, Pitman House, Parker Street, Kingsway, London, W.C.2.* (37*s.* 6*d.*)

The tenth edition of "Lewitt" has been re-set throughout and some of the material has been re-written to bring it into line with revised professional and degree examination syllabuses in fluid mechanics. In particular, the section on the effects of supersonic speed has been brought up to date and expanded. New chapters have been added on the frictional flow of gases through tapering pipes and through ducts of any cross-section, the equations developed being applicable to the design of nozzles, diffuser and blade passages through axial and radial-flow gas turbines.

Construction of Buildings in London. *London County Council, County Hall, Westminster Bridge, London, S.E.*1; and *Staples Press Limited, 14 Great Smith Street, Westminster, London, S.W.*1. (17*s.* 6*d.*)

The 1958 edition gathers together most of the information needed by architects, engineers and surveyors concerned with building requirements in London. The contents include important parts of the London Building Acts and By-laws, the Factories Act, 1937, and the Acts governing the use of celluloid, together with other regulations which amplify and explain them. There is also a list of useful British standards and publications covering most aspects of building work. There is a comprehensive index.

History of Hydraulics. By HUNTER ROUSE and SIMON INCE. *Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City.* (5 dols.)

The primary theme, the authors state, is the "formulation of the underlying principles of fluid motion, incorporating such aspects of experimentation, engineering application, related scientific progress, and world history as seemed to bear on that theme." It is developed from early antiquity up to the present-day state of the science, and demonstrates how, as such principles gradually came to light, they were the common property of scientists and engineers. But with further progress, divergences occurred, at first between the scientists and engineers, and then among the engineers themselves. In the early part of the present century, the rise of a new branch of science, "fluid mechanics" has already bridged the gap between theory and practice in aerodynamics and is increasingly permeating the field of hydraulics generally.

On the Shelf

By Frank H. Smith

It is rather surprising to see in a technical periodical, *Mechanical Engineering*, an article by a vice-president of the United States entitled "Sharpen the Truth." This title is an insert in a headline which reads "The problem is to *sharpen the truth* into a weapon as effective and devastating as the Soviet lie." And at the foot appears a supplementary title "We cannot use the communist technique of the measured lie . . ." The article is not made any more potent by the opening paragraph "With the race to outer space temporarily tied, numerically at least, at two each, this would seem to be an appropriate time to put the dramatic events of the past six months in perspective." The issue arrived in this country a few days after the Russians had put their third and biggest Sputnik up.

Jet Propulsion (a publication of the American Rocket Society, together with the American Interplanetary Society, 20th and Northampton Streets, Easton, Pa., and, editorially, 500 Fifth Avenue, New York, 36) has, in the May number, "Artificial Satellites—a Bibliography of Recent Literature Part One—1956." This is annotated, 340 references alphabetical by author, and is an up-to-datery of one published in the same journal in May, 1956. Part 2 of the bibliography from January, 1957, "through" February, 1958, will appear later and I will do my best to keep my eyes skinned for it for you, my gracious reader. This, incidentally, is another of those journals which make you wonder where the Americans find (*a*) the time (*b*) the material to indulge in such masses of writing.

The series on "Electroanalogic Methods" in *Applied Mechanics Reviews* is up to Part VI in the May number. This deals with "multiplication of grid-network efficacy by use of 'tearing'." The references run from 977 to 1046 which constitutes quite a bit of reading.

The *Inco-Mond Magazine* No. 6 (Mond Nickel Company, Thames House, Millbank, S.W.1) has, among the technical stuff about fat-splitting, automatic transmission systems and dairy education, two articles of more general interest. One deals with how they make nibs for fountain pens (from which one learns that, to the maker, a nib is a pen) and the other deals with those fascinating little glass figures one can buy from hawkers in Oxford Street for pennies and from Burlington Arcade for guineas. The illustration to the second article is a charming photograph of 22 blue penguins with red beaks in various sizes (the penguins not the beaks). One learns that the reason why so many of these animals and birds are quaint caricatures is that "Glass is not as well suited for the reproduction of detail as it is for form. It is possible to create a well-rounded leg; a foot with toes true to life is hardly practicable." With reference to that last sentence, how many men worry about the latter when inspecting the former?

I wonder what the new Oxford dictionary will do with "do-it-yourself." I see that *Nature* heads a review of *Methods in Enzymology*—"Enzymologists' 'do-it-yourself' manual."

With *Esso Air World*, May-June, 1958, there is a useful supplement, "Airline Orders for Civil Aircraft: with years of delivery: 1957-63." The table gives the name of the airline, the type of aircraft by name, and the number for delivery in a given year. The only items for 1963 are 24 DH121 for BEA and 35 Vickers VC-10 for BOAC so Hatfield and Weybridge, at least, have something to look forward to for the next five years.

The British Welding Research Association (29 Park Crescent, W.1) put out a neat little folder listing their publications and prices thereof. They range from "The Radiographic Examination of Welds in Mild Steel Plates by X- and Gamma-ray Sources and some Observations on ASME, BWRA and DIN Penetrameters" at 1*s.* 6*d.*, to "The Welding of Austenitic Corrosion and Heat Resisting Steels," at 27*s.* 6*d*

Production

CURVED SAFETY GLASS

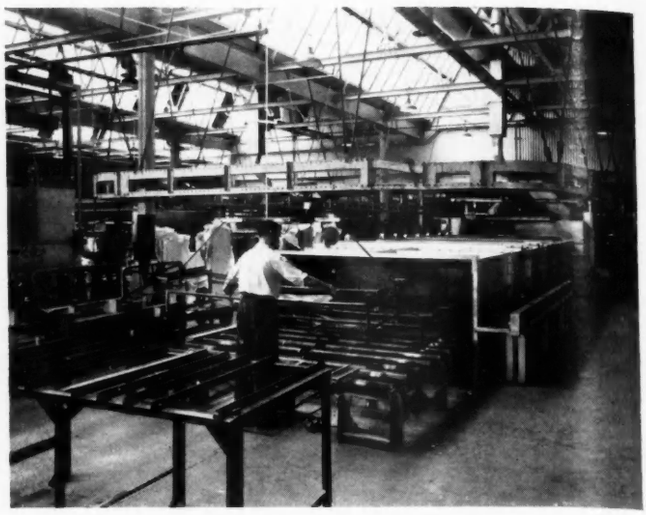
The popularity of curved and "wrap-round" screens and rear windows on cars and commercial vehicles is evident from the number which can be seen on the roads to-day, and the demand is growing. It may not be known generally, however, that such screens must be capable of being produced in either of two basic types of safety glass, toughened or laminated, to suit the requirements of different markets. Vehicles sold in Great Britain, for example, are fitted with toughened safety glass, but for North America and certain other overseas markets laminated glass is necessary.

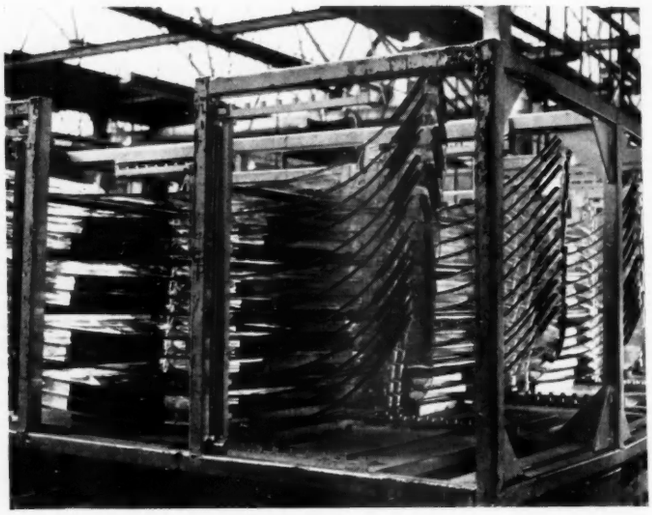
Both types of safety glass, in curved and flat forms, are produced by the Triplex Safety Glass Company Limited, King's Norton, Birmingham, 30. Demand for the curved laminated types has developed to such an extent that it has been necessary to build a new department for producing these screens, and 50 extra skilled workers have been engaged. About 14,000 curved laminated screens will be produced weekly in the new department, which will operate on a three-shift basis, and it is estimated that 75 to 80 per cent of the output will be exported on finished vehicles. The new department will run in parallel with the other production departments at the works, where laminated flat safety glass is made for car windows and ventilators and toughened glass is produced in both curved and flat forms, and special-purpose safety glass components, such as aircraft windows, are made to very exacting specifications.

(Right) Glasses being curved before lamination in a continuous furnace at the Triplex works.

(Below, left) Assembly of glass and interlayer material is done in a dust-free, air-conditioned room.

(Below, right) Final adhesion and full visual clarity are obtained by treatment in an autoclave. Screens are stacked in special crates, as seen here, for loading to the autoclave.





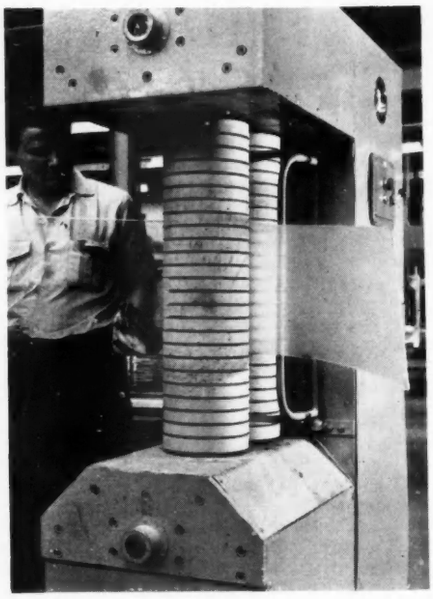
BASIC GLASS TYPES

Laminated glass, the original type of safety glass, is of sandwich construction, consisting of two thin pieces of glass and between them a piece of plastic reinforcing material, to which the glass is firmly united. If this glass is broken the panel remains intact except under conditions of very violent impact, and in any case, even if the panel is smashed completely, the pieces of glass are held by the plastic, and severe cuts are prevented. Originally the plastic "interlayer" as it is called, was celluloid, but this material was liable to turn brown on exposure to sunlight, and it has been superseded by a stable plastic which gives no trouble in this respect. The material used by Triplex is polyvinyl-butyral, generally known as "vinal"; it does not discolour or bubble, and it sticks to glass extremely well under suitable conditions of heat and pressure.

Toughened glass is made by a pre-stressing technique, in which a piece of glass, cut to size and shape, is heated to its softening point and then chilled by air blasts on both sides simultaneously. Its strength is increased by a factor of five or six, and when it does break it shatters completely into a mass of fine particles with dull edges, incapable of causing severe cuts. Toughened glass cannot be cut or shaped after heat treatment; it must therefore be completely finished as regards size, shape and surface condition before it is toughened.

In the production of toughened glass the raw material, flat sheet or plate glass, purchased from outside suppliers, is first examined carefully for flaws, and the accepted pieces are then cut to shape, both hand and machine cutting being employed. Edge preparation follows, the edges being either bevelled slightly if they will be concealed completely by the mounting, as on car windscreens, or polished if they will be exposed in part, as on car winding windows. This polishing operation is carried out on automatic machines. Every piece of glass is then washed and dried by machine, to remove glass powder and abrasive which might otherwise become fused to the surface in the heat treatment which follows.

Flat glasses are suspended from tongs on a special rig and lowered into an electric furnace one at a time; they remain there until the required temperature of between 600 and 700° C is reached. The glass is then lifted out of the furnace as quickly as possible and cooled by compressed air from a series of pipes arranged in blowing frames, which reciprocate or oscillate



After heating, laminated screens are rolled between rubber rollers to provide preliminary adhesion and visual clarity.

to give complete air coverage of the hot glass. Chilling is completed in 15 to 20 seconds, and the glass, still too hot to be handled normally, is removed by an operator wearing asbestos gloves. Final inspection follows, and this includes a test blow from an automatic hammer which corresponds roughly with the impact of a steel ball weighing 1¾ lb falling from a height of 4 ft 6 in. The glass stress pattern is also checked by polarised light. If the piece passes the tests it is marked with the Triplex trade mark by abrasive blasting, and goes to the packing department.

Where a piece is required to be curved it is bent immediately before chilling, by automatically-operated formers and dies. Furnace conditions are controlled to very close limits, and are so set that when a piece of toughened glass is broken under certain conditions the size of the resulting particles will be 20 per sq. in, or slightly more.

LAMINATING

Laminated, like toughened, glass, is produced in both flat and curved forms. For laminating, glass is first inspected, cut to size, and then washed and dried mechanically, and in this condition it is ready to be assembled with the laminating material if it is flat. If curved, the glass is bent to shape before laminating, 14 furnaces for this purpose having been installed in the new department. Two of these furnaces are continuous in operation.

Some preparation is also necessary on the vinal plastic interlayer material before it passes to meet the glass in a special assembly room. Vinal is received in rolls, which are first dried to reduce the moisture content to about 0·2 per cent, and then taken to an air-conditioned room, with a relative humidity of not more than 30 per cent, where the material is cut into pieces of the required shape, but slightly oversize, by means of templates and razor blades. Since the vinal is comparatively soft it is dusted on both sides with finely powdered bicarbonate of soda, to prevent it sticking together when in the roll form. This powder has to be washed off, with jets of warm water, and the material is then dried again before passing into the assembly room.

It is obviously of vital importance that dirt, dust and other foreign matter shall be prevented from entering the sandwich lamination during processing, and for this reason the actual assembly of glass and interlayer is done in an air conditioned, dust-free room, by operators wearing special lintless nylon overalls. Glass and interlayer enter by conveyor, having been mechanically washed and dried. Relative humidity in the room is kept to not more than 30 per cent, and the temperature is controlled at 60° F, so reducing the tendency of the pieces of washed interlayer to stick together.

On leaving the assembly room the sandwiches of two pieces of glass and interlayer pass between electric heaters and rubber rolls to bring about preliminary adhesion, but on emergence from the rolls the glass is still only partly clear and full adhesion has not developed. After roll-pressing, therefore, the glasses are stacked into steel crates, with plastic spacers to keep them about ⅜ in apart and so allow the heat in the next process to reach all parts. They are then wheeled into an autoclave, where air at 100 lb per sq. in is admitted and heating continues until the internal temperature reaches rather more than 100° C. Slow cooling follows, and the glass only requires edge finishing, inspection and marking before passing to the packing room.

SPECIAL APPLICATIONS

A very high standard of quality is maintained for automobile glass, but for aircraft work the requirements, both for safety and optically, are exacting in the extreme. Aircraft windows are in regular production to withstand temperatures down to − 70° C, in pressurised cabins, and to be proof against the impact of birds weighing up to 14 lb. In military aircraft the windows may have to be bullet-proof. To meet such requirements Triplex make windows which are both toughened and laminated, sometimes with extra-thick vinal interlayers which project beyond the glass and are used for fixing purposes. Double glazing units are also made as well as panels electrically wired for de-frosting. For this purpose the more recent development, the use of which is expanding, is the Triplex gold film glass. This has a gold film so thin (two ten-millionths of an inch) that it is quite transparent and does not glitter, yet will carry power inputs of 600 watts per sq. ft or even higher.

Design

LUBRICATION OF PLAIN BEARINGS

Applicability of Reynolds's Hydrodynamic Theory

By J. H. Halton, M.A.*

This article is a digest of a paper, by the present author, entitled "The Lubrication of Plain Bearings: An Examination of Reynolds's Hydrodynamic Theory," in which can be found the details of mathematical proofs, experimental evidence, and a survey of previous treatments of the theory, all omitted here.

An examination of published work on the theory of thick-film (hydrodynamic) lubrication reveals that it is almost entirely based on Reynolds's treatment. Very little consideration is generally given to the basis of the theory, and the resulting equations and formulae are applied quite indiscriminately in the design and evaluation of bearings. An attempt has now been made to find the least restrictive assumptions on which a generalised Reynolds equation can be based. From these assumptions, a series of tests is derived, which a plain journal bearing must satisfy, if formulae based on Reynolds's theory are to be applied to it with any chosen accuracy.

The Assumptions.—1. The minimum film-thickness of the lubricant is much larger than its molecular dimensions. 2. The irregularities of the bearing surfaces (roughness) and of the lubricant (dust, metal, bubbles) are much smaller than the minimum film-thickness. 3. Newtonian viscosity (this is also true of ordinary fluids at sufficiently low rates of shear). 4. No turbulence or vortex flow. 5. The film-thickness is much smaller than the radii of curvature of the bearing surfaces. 6. Roughness apart, the relative variations in film-thickness are small over a region of the bearing surfaces (region of contact) very much larger than the film-thickness. 7. Tangentially, pressure-forces are much greater than inertia-forces. 8. Fluctuations of velocity with time are very small, in comparison with tangential velocities, and are not much faster than the tangential gradient of the velocities. 9. Normal forces are not much greater than pressure gradients in tangential directions. 10. The same is true of normal temperature gradients. 11. Tangentially, the relative gradients of density and viscosity are not much greater than those of tangential velocities. 12. The same is true of the higher derivatives of density and viscosity. 13. The bearing surfaces are rigid. 14. No slip: the velocities of bearing surfaces and lubricant, where they meet, are equal. In addition, either (15) pressure gradients are not much greater tangentially than normally (See 9), and (16) the same for temperature gradients (See 10); or (17) tangentially, relative gradients of viscosity are much smaller than those of tangential velocity (See 11), and (18) the ratio of first to second normal derivatives of the velocity is not much greater than the radius of curvature of the bearing surfaces; or (19) the former is much smaller than the latter (See 18).

Assumptions 1, 2, 3 and 4 allow the lubricant to be treated as a homogeneous Newtonian fluid in laminar flow. If it has density ρ, viscosity η, specific heat (at constant pressure, in energy units) C, and thermal conductivity (in energy units) K, when the pressure is p and the absolute temperature T; and if the velocity of the lubricant is $\mathbf{u} = (u, v, w)$; then the equations governing the flow are

$$\frac{\partial \rho}{\partial t} + \operatorname{div}(\mathbf{u}\rho) = 0 \quad . \quad . \quad (1)$$

$$\rho\left(\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \,.\, \operatorname{grad} \mathbf{u}\right) = \rho\mathbf{g} + \operatorname{div} \mathbf{G} \quad . \quad . \quad (2)$$

where $\mathbf{g}$ is the body-acceleration (normally, just the constant gravitational acceleration) and $\mathbf{G}$ is the stress-tensor for the lubricant,

$$\mathbf{G} = 2\eta \operatorname{sym} \operatorname{grad} \mathbf{u} - \frac{2}{3}\eta(\operatorname{div} \mathbf{u})\mathbf{I} - p\mathbf{I} \quad . \quad . \quad (3)$$

and

$$\frac{\mathrm{T}}{\rho}\frac{\partial \rho}{\partial \mathrm{T}}\left(\frac{\partial p}{\partial t} + \mathbf{u} \,.\, \operatorname{grad} p\right) + \rho \mathrm{C}\left(\frac{\partial \mathrm{T}}{\partial t} + \mathbf{u} \,.\, \operatorname{grad} \mathrm{T}\right) - p \operatorname{div} \mathbf{u} = \mathbf{G} : \operatorname{grad} \mathbf{u} + \operatorname{div}(\mathrm{K} \operatorname{grad} \mathrm{T}) \quad . \quad . \quad . \quad (4)$$

It can be shown that the effect of bearing surface roughness can be ignored if temperature, pressure, and velocity are taken to have the magnitudes measured by probes; that is, are averaged over regions of the film whose dimensions are not much smaller than the film-thickness. By applying the assumptions stated above to equations (1) to (4), we obtain, after some mathematical manipulation, the generalised Reynolds equation:

$$\frac{\partial}{\partial x}\left(h^3 \frac{\rho}{\eta}\frac{\partial p}{\partial x}\right) + \frac{\partial}{\partial y}\left(h^3 \frac{\rho}{\eta}\frac{\partial p}{\partial y}\right) + 6\rho\left[(\mathrm{U}' - \mathrm{U})\frac{\partial h}{\partial x} + (\mathrm{V}' - \mathrm{V})\frac{\partial h}{\partial y}\right] = 12\rho(\mathrm{W}' - \mathrm{W}) + 12h\left[\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}\left(\rho\frac{\mathrm{U}' + \mathrm{U}}{2}\right) + \frac{\partial}{\partial y}\left(\rho\frac{\mathrm{V}' + \mathrm{V}}{2}\right)\right] \quad . \quad . \quad . \quad (5)$$

and a corresponding energy equation:

$$\left(\frac{\mathrm{T}}{\rho}\frac{\partial \rho}{\partial \mathrm{T}} + 1\right)\left[\left(\frac{\partial p}{\partial x}\right)^2 + \left(\frac{\partial p}{\partial y}\right)^2\right] + \rho \mathrm{C}\left(\frac{\partial p}{\partial x}\frac{\partial \mathrm{T}}{\partial x} + \frac{\partial p}{\partial y}\frac{\partial \mathrm{T}}{\partial y}\right) + 12\frac{\eta^2}{h^4}[(\mathrm{U}' - \mathrm{U})^2 + (\mathrm{V}' - \mathrm{V})^2] + \frac{12\eta}{h^3}\operatorname{div}(\mathrm{K} \operatorname{grad} \mathrm{T}) = \frac{6\eta}{h^2}\frac{\mathrm{T}}{\rho}\frac{\partial \rho}{\partial \mathrm{T}}\left[(\mathrm{U}' + \mathrm{U})\frac{\partial p}{\partial x} + (\mathrm{V}' + \mathrm{V})\frac{\partial p}{\partial y}\right] + \frac{6\eta\rho\mathrm{C}}{h^2}\left[(\mathrm{U}' + \mathrm{U})\frac{\partial \mathrm{T}}{\partial x} + (\mathrm{V}' + \mathrm{V})\frac{\partial \mathrm{T}}{\partial y}\right] + \frac{12\eta}{h^2}\left(\frac{\mathrm{T}}{\rho}\frac{\partial \rho}{\partial \mathrm{T}}\frac{\partial p}{\partial t} + \rho \mathrm{C}\frac{\partial \mathrm{T}}{\partial t}\right) \quad . \quad . \quad . \quad (6)$$

where x and y are pseudo-Cartesian co-ordinates tangential to the bearing surfaces, h is the film-thickness (at x and y), $\bar{h}$ is the mean film thickness, and the local velocities of the bearing surfaces are $\mathbf{U} = (\mathrm{U}, \mathrm{V}, \mathrm{W})$ and $\mathbf{U}' = (\mathrm{U}', \mathrm{V}', \mathrm{W}')$

The Tests.—There may now be considered a journal bearing of diameter D, length (width) L, radial clearance $\bar{h}$, running at N revolutions per unit time, under a load W. The lubricant

* Balliol College, Oxford.

Continuing **Design**

has parameters ρ, η, C, defined above, and

$$\sigma_1 = \frac{1}{\rho}\frac{\partial \rho}{\partial p}, \quad \sigma_2 = \frac{1}{\eta}\frac{\partial \eta}{\partial p}, \quad \sigma_3 = \frac{1}{\rho}\frac{\partial \rho}{\partial \mathrm{T}}, \quad \sigma_4 = \frac{1}{\eta}\frac{\partial \eta}{\partial \mathrm{T}} \quad . \quad . \quad . \quad (7)$$

It runs through the bearing with inlet and outlet temperatures T_1 and $T_2 = T_1 + \theta$, and the eccentricity ratio of the running bearing is n. Young's modulus for the bearing material is Y. Two sets of units are used, as given in Table I.

The quantities D, L, $\bar{h}$, N, W, ρ, η, and T_1 will be given. The following may be taken as rough general estimates, in the absence of more specific information.

$\sigma_1 = 5 \times 10^{-11}$ c.g.s. or 3×10^{-6} c.u.,
$\sigma_2 = 1{\cdot}5 \times 10^{-9}$ c.g.s. or 10^{-4} c.u.,
$\sigma_3 = 6 \times 10^{-4}$ c.g.s. or 4×10^{-4} c.u.,
$\sigma_4 = 5 \times 10^{-2}$ c.g.s. or 3×10^{-2} c.u. . (8)

(These values are given for typical lubricating oils.)

$$\mathrm{Y} = 1{\cdot}6 \times 10^{11} \text{ c.g.s. or } 1{,}000 \text{ c.u.} \quad . \quad (9)$$

At the design stage, θ and n will have to be estimated. Crude approximations are given by the formulae

$$\theta = 1{\cdot}7 \times 10^{-6} \text{ (c.g.s.), or } 1{\cdot}1 \times 10^{-5} \text{(c.u.)}, \times \left(\frac{\eta^2 \mathrm{N}^2 \mathrm{D}^4}{\rho \mathrm{C} \mathrm{P} \bar{h}^4}\right) \quad . \quad . \quad . \quad (10)$$

and

$$\frac{n}{(1 - \frac{3}{8}n^4)} = 7 \times 10^{-2} \text{ (c.g.s.), or 7 (c.u.)}, \times \left(\frac{\mathrm{W} \bar{h}^2}{\eta \mathrm{N} \mathrm{L} \mathrm{D}^3}\right) \quad . \quad . \quad . \quad (11)$$

where the lubricant feed-pressure is P, and n is the solution of (11) in (0, 1).

The tests are most easily expressed in terms of the following parameters.

$$\alpha = \frac{\bar{h}}{\mathrm{D}}, \quad \beta = \frac{\mathrm{L}}{\mathrm{D}}, \quad \lambda = \frac{\eta \mathrm{N} \mathrm{L} \mathrm{D}^2}{\mathrm{W} \bar{h}}, \quad \nu = \frac{\rho \mathrm{N} \mathrm{D} \bar{h}}{\eta}, \quad \omega = \frac{\mathrm{W}}{\mathrm{L} \mathrm{D}} \quad . \quad . \quad . \quad (12)$$

together with D, N, ρ, Y, σ_1, σ_2, σ_3, σ_4, and θ. They fall into three groups, given in Tables II, III, and IV.

If the level of accuracy of the work is $A (0 < A < 1)$, it means that, when a quantity $\mathbf{Q}$ is considered, any error smaller than $A\,\mathbf{Q}$ is allowed and neglected. It is said that "$\mathbf{Q}_1$ is of greater magnitude than $\mathbf{Q}_2$" if the latter is negligible in comparison with the former, at the level of accuracy A. This is written

$$\mathbf{Q}_1 >^{\circ} \mathbf{Q}_2, \text{ or } \mathbf{Q}_2 <^{\circ} \mathbf{Q}_1, \text{ iff } A\,|\mathbf{Q}_1| > |\mathbf{Q}_2| \quad (13)$$

(where " iff " is an abbreviation for " if and only if.") This is called a *strong inequality of magnitude*. Such an inequality will be obeyed for all values of A greater than $|\mathbf{Q}_2/\mathbf{Q}_1|$, and so it will set a lower limit, or best allowed accuracy, min (A). If $|\mathbf{Q}_2| > |\mathbf{Q}_1|$, the inequality is not satisfied at all.

It is said that "$\mathbf{Q}_1$ is not of greater magnitude than $\mathbf{Q}_2$" if the relation (13) does not hold. This is written

$$\mathbf{Q}_1 \not>^{\circ} \mathbf{Q}_2, \text{ or } \mathbf{Q}_2 \not<^{\circ} \mathbf{Q}_1, \text{ iff } A\,|\mathbf{Q}_1| < |\mathbf{Q}_2| \quad (14)$$

and is called a *weak inequality of magnitude*. Such an inequality is obeyed for all values of A less than $|\mathbf{Q}_2/\mathbf{Q}_1|$, thus setting an upper limit, or worst allowed accuracy, max (A). If $|\mathbf{Q}_2| > |\mathbf{Q}_1|$, the inequality is satisfied for all A.

We interpret *equality of magnitude* as follows:—

$$\mathbf{Q}_1 =^{\circ} \mathbf{Q}_2, \text{ iff } \mathbf{Q}_1 \not>^{\circ} \mathbf{Q}_2 \text{ and } \mathbf{Q}_2 \not>^{\circ} \mathbf{Q}_1 \quad . \quad . \quad . \quad (15)$$

thus,

$$\mathbf{Q}_1 =^{\circ} \mathbf{Q}_2, \text{ iff } A < \text{min.}\{|\mathbf{Q}_1/\mathbf{Q}_2|, |\mathbf{Q}_2/\mathbf{Q}_1|\} \quad . \quad . \quad . \quad (16)$$

This, therefore, is a relation of the "weak" type.

It follows from this that the tests in Table III give a combined minimum value of A, and those in Table IV give a combined maximum. If the "absolute" tests in Table II give negative results, or if it turns out that min $(A) >$ max (A) or that the allowed range of accuracies is too high (say over 30 per cent), then it appears that the assumptions on which Reynolds's theory is based are unwarranted in the given case, and so the results based on this theory cannot be applied without the risk of large errors, and of being considerably misled.

The tests were applied to ten typical heavy-machinery bearings: G1, G2, and G3 are gas-turbine bearings; S4, S5, and S6 are steam-turbine bearings; W7 and W8 are water-turbine bearings; and D9 and D10 are diesel-engine bearings. Table V gives the data for these bearings.

The results of the tests are summarised in Table VI. Values in parentheses are those obtained when the rejecting tests are omitted.

It is clear from these results that the applicability of Reynolds's theory to bearings used in modern high-performance machinery is not as wide as is generally supposed. The rejecting tests are 2 and 19; the former refers to assumption (4) (of non-turbulent flow), and the latter to assumption (11), in its application to thermal variations in the viscosity of the lubricant.

The author wishes to thank the English Electric Company Limited (in whose mechanical engineering laboratory this work was carried out during the period March, 1955, to October, 1956) for permission to publish his results, and Mr. G. F. W. Adler and Mr. M. P. Newby for their encouragement of the work.

Photocopies of the complete paper, which includes a bibliography of 56 items, are obtainable from the Publisher, ENGINEERING, 36 *Bedford Street, Strand, London, W.C.2. Price* 15*s.* (*Canada and the United States* 2·50 *dol*), *post free. Orders should be accompanied by a remittance.*

TABLE I.—*C.G.S. and Customary Units*

Quantity	C.G.S. unit	Customary unit (C.U.)
L, D	cm.	in = 2·54 cm
$\bar{h}$	cm.	h.t. = in/2,000 = 0·00127 cm
N	$sec.^{-1}$	r.p.m. = $min.^{-1}$ = 0·0167 sec^{-1}
W	dyne	lb wt. = 445,000 dynes
ρ	gm. $cm.^{-3}$	gm. cm^{-3}
η	poise = gm. $cm.^{-1}$ sec^{-1}	cp. = 0·01 poise
T_1, T_2, θ	°K = °C Abs.	°F Abs.
p	dyne $cm.^{-2}$	lb/sq. in = lb wt. in^{-2} = 69,000 dynes cm^{-2}
Y	dyne $cm.^{-2}$	ton in^{-2} = 1·55 × 10^8 dynes cm^{-2}
σ_1, σ_2	dyne^{-1} $cm.^2$	lb $wt.^{-1}$ in^2 = 1·45 × 10^{-5} $dyne^{-1}$ cm^2
σ_3, σ_4	$(°C)^{-1}$	$(°F)^{-1}$ = 1·8 $(°C)^{-1}$
C	cal. $gm.^{-1}$ $(°C)^{-1}$	B.t.u. lb^{-1} $(°F)^{-1}$ = cal. $gm^{-1}(°C)^{-1}$

TABLE II.—*Absolute Inequalities*

Test	Parameter	Relation	C.G.S. criterion	C.U. criterion
1	$\omega\lambda/(1 - n)$	$<$	$1{\cdot}6 \times 10^5$	$4{\cdot}8 \times 10^5$
2	$\nu\sqrt{\alpha}$	$<$	9·2	$7{\cdot}6 \times 10^4$

TABLE III.—*Strong Inequalities of Magnitude*

Test	Parameter	Relation	C.G.S. criterion	C.U. criterion
3	α	$\not<^{\circ}$	0·5	10^3
4	$(n/1 - n)\,\alpha\,\nu$	$\not<^{\circ}$	1·5	$5{\cdot}6 \times 10^5$
5	$\beta^2\lambda/\alpha^2\nu$	$\not>^{\circ}$	0·12	$3{\cdot}4 \times 10^{-5}$
6	$\alpha\,\beta\,\lambda\,\nu\,n/(1 - n)^3$	$\not<^{\circ}$	3·5	$2{\cdot}7 \times 10^{11}$
7	$\alpha(1 - n)\,\mathrm{Y}/\omega$	$\not>^{\circ}$	0·92	0·83
8	$\omega/\rho\,\mathrm{D}$	$\not>^{\circ}$	$2{\cdot}1 \times 10^2$ or $1{\cdot}3 \times 10^2\,\beta$	$7{\cdot}7 \times 10^{-3}$ or $4{\cdot}9 \times 10^{-3}\,\beta$
9	$\lambda\,\nu\,n$	$\not>^{\circ}$	0·75 or $2{\cdot}3\,(1 - n)$	$2{\cdot}9 \times 10^7$ or $0{\cdot}88 \times 10^8\,(1 - n)$
10	$\lambda/(1 - n)$	$\not<^{\circ}$	0·75	$1{\cdot}6 \times 10^5$

TABLE IV.—*Weak Inequalities of Magnitude*

Test	Parameter	Relation	C.G.S. criterion	C.U. criterion
11	$n/(1 - n)$	$\not>^{\circ}$	1	1
12	β	$=^{\circ}$	1	1
13	$(n/1 - n)\,\lambda$	$\not>^{\circ}$	0·59 or $0{\cdot}93/\beta$	$1{\cdot}2 \times 10^5$ or $1{\cdot}9 \times 10^5/\beta$
14	$\lambda\nu$	$\not>^{\circ}$	0·71 or $1{\cdot}1/\beta$	$2{\cdot}7 \times 10^7$ or $4{\cdot}3 \times 10^7/\beta$
15	$\alpha\nu$	$\not>^{\circ}$	3·8 or $2{\cdot}4\,\beta$	$1{\cdot}4 \times 10^6$ or $0{\cdot}90 \times 10^6\,\beta$
16	$\sigma_1\omega(1 + n/n)$	$\not>^{\circ}$	0·54	0·54
17	$\sigma_2\omega(1 + n/n)$	$\not>^{\circ}$	0·54	0·54
18	$\sigma_3\theta(1 + n/n)$	$\not>^{\circ}$	1	1
19	$\sigma_4\theta(1 + n/n)$	$\not>^{\circ}$	1	1

TABLE V.—*Bearing Data*

Bearing	L (in)	D (in)	$\bar{h}$ (h.t.)	N (r.p.m.)	W (lb wt.)	θ (°C)	η (cp.)	$\sigma_4(°C)^{-1}$	n (est.)
G1	2·0	5·0	9	8,000	1,000	15	8	0·027	0·035
G2	1·6	5·0	12	9,000	100	15	8	0·027	0·007
G3	4·0	13·0	15	3,000	6,000	8	10	0·021	0·036
S4	5·5	5·7	12	3,000	2,000	16	34	0·057	0·019
S5	3·0	10·0	17	3,000	2,000	26	20	0·044	0·022
S6	11·0	13·0	20	3,000	18,000	31	16	0·037	0·043
W7	25·5	15·0	9	150	300,000	15	48	0·043	0·274
W8	29·0	20·0	10	428	75,000	40	17	0·033	0·031
D9	3·2	7·2	9	850	50,000	6	25	0·034	0·873
D10	6·6	12·0	8	428	60,000	11	36	0·038	0·153

ρ takes values between 0·83 and 0·87; $\sigma_1 = 3{\cdot}2 \times 10^{-6}$; $\sigma_2 = 10^{-4}$; σ_3 is between 6·4 and 6·6 × 10^{-4}. n was estimated from (11). Y was taken to be 1,000 tons in.$^{-2}$.

TABLE VI.—*Applicability of the Assumptions*

Bearing	Tests 1 and 2	Min (A) per cent	Max (A) per cent	Rejecting test
G1	—	7	8 (100)	19*
G2	Fails 2	5	2 (88)	19
G3	—	10	21	—
S4	—	<1	2 (100)	19*
S5	—	<1	2 (100)	19*
S6	—	2	4 (100)	19*
W7	—	<1	33	—
W8	—	<1	2 (100)	19*
D9	—	7	15	—
D10	—	<1	32	—

* In these cases, although the tests are formally satisfied, the range of accuracies allowed is too short to give reliable results.

PROTECTING AIRCRAFT FROM ICE

Concurrently with their 150th anniversary celebrations, the Luton branch of D. Napier and Sons Limited (makers of the Spraymat electrical de-icing system, described in ENGRG., *vol.* 177, 1956, *p.* 379) *held a one-day aircraft ice protection conference—believed to be the first such conference ever held—which was attended by over 120 delegates from aircraft, engine and propeller manufacturers, airlines, government establishments, and the technical Press, and including representatives from Canada, France, Holland, Israel, and the United States.*

Five papers were discussed; "Icing Standards and Methods used to Determine the Suitability of Aircraft to Fly in Icing Conditions," by Mr. H. E. Le Sueur, Air Registration Board; "Some Aspects of Engine Icing," by Mr. W. Sherlaw, Rolls-Royce Limited; "Electric or Hot Gas Thermal Ice Protection?" by Mr. J. A. Hay, Vickers-Armstrongs (Aircraft) Limited; "Aircraft Electrical Heater Mats and Future Developments," by Dr. R. A. Roper, D. Napier and Son Limited; and "Development of Ice Protection Control Systems," by Mr. E. O. Robertson, Canadian Applied Research Limited.

The collective digest which follows, outlines present-day thinking on aircraft ice protection as depicted by the conference papers and discussions.

ICE FORMATION

Ice accretion on the airframe and engine installation in flight may be formed in either of two ways: most frequently, by minute droplets of "super-cooled" water impinging and freezing on the exposed surfaces of the aircraft; and more rarely, due to minute ice crystals which may collect in air-intake scoops and forward-facing instrument pitot tubes, causing blockage or, if they strike a heated surface, they may melt and refreeze later.

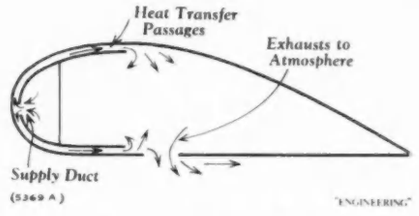
The propulsive units and essential instruments must continue to function satisfactorily, however severe the icing conditions encountered. The airframe, on the other hand, is expected to be able to carry a certain amount of ice without too seriously impairing its performance and control characteristics; hence, design requirements specify continuous icing conditions extending up to 30,000 ft for both airframes and engine, and more severe intermittent conditions extending up to 40,000 ft for engines only, in which the aircraft must be able to operate satisfactorily. Not that it is desirable for an aircraft to be flown deliberately into the core of an ice-forming thunderstorm, where it might encounter violent turbulence and hailstones up to $5\frac{1}{2}$ in diameter—but, on regular services, it may be impossible to avoid ice-forming conditions entirely; and cloud and collision warning radar is not yet 100 per cent reliable in warning crews of storm areas.

AIRFRAME ICE PROTECTION

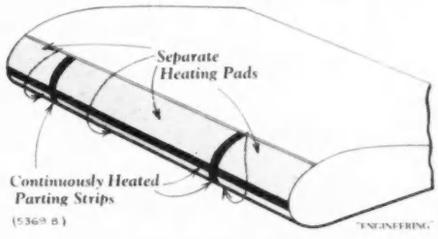
Three principal methods of protecting airframes from ice build-up have been developed: mechanical (inflatable "boots"), chemical, and thermal. The first two systems are developed and still widely in use, but it is in the newer thermal methods that most aircraft designers are interested to-day.

Thermal de-icing systems sub-divide into continuously-heated and intermittently-heated systems—and where the main-wing and tail-plane surfaces are concerned, continuously-heated systems utilise hot gas conducted in leading-edge ducts, and intermittently heated systems use cyclic electro-thermal surface-heated mats. (Cyclic hot-gas systems are under development, but are not yet proved; and, of course, continuously-heated electro-thermal systems are in use for air intakes, windscreens and subsidiary surfaces).

Hot gas systems may be of two types. Where turbojet engines are installed, a direct bleed from the compressor may supply hot gas for de-icing. In the case of turbo-prop installations, direct bleed may penalise engine performance too heavily, and therefore an exhaust-heated heat exchanger may be used to warm ram air for de-icing purposes. Both these systems require heating coverage, in the form of a double-skin duct along the leading edge, extending 10 to 15 per cent of the chord back from the leading edge. In the cyclic electro-thermal de-icing system, ice is allowed to accumulate in the "catch" region, up to a thickness of, say, $\frac{1}{16}$ in, and is then shed by applying a high rate of heating for a short time to the heater mat, which is wrapped around the aerofoil surface. Once the layer bonding the ice to the surface is melted, aerodynamic forces will attempt to remove the accumulation. For this to be effective, continuously-heated parting strips are necessary along the leading edge and between adjacent cyclic zones.



Typical section of hot gas system.



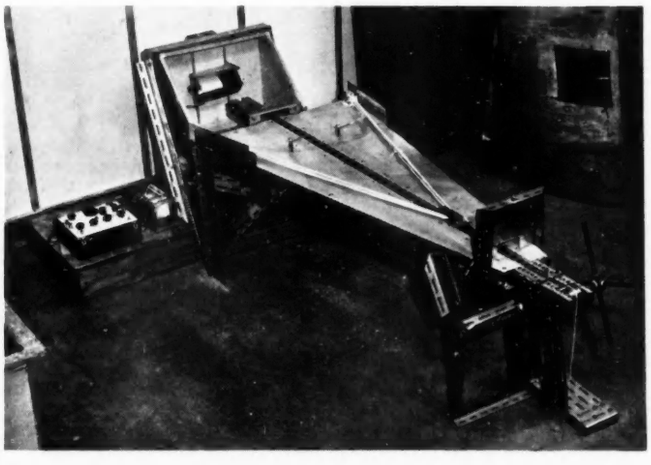
Typical arrangement of cyclic electrical de-icing system. Current is supplied to the heating pads one at a time to shed local ice.

Briefly, the relative merits of hot-gas and cyclic electro-thermal de-icing appear to be as follows: generally, the electrical system requires less space and consumes considerably less power while in operation. In dead weight there is little to choose between the systems, the electrical one being perhaps slightly heavier (this trend would, however, tend to be reversed in the next generation of aircraft with tail-situated engines where hot-gas de-icing would mean long gas ducts through the pressurised fuselage).

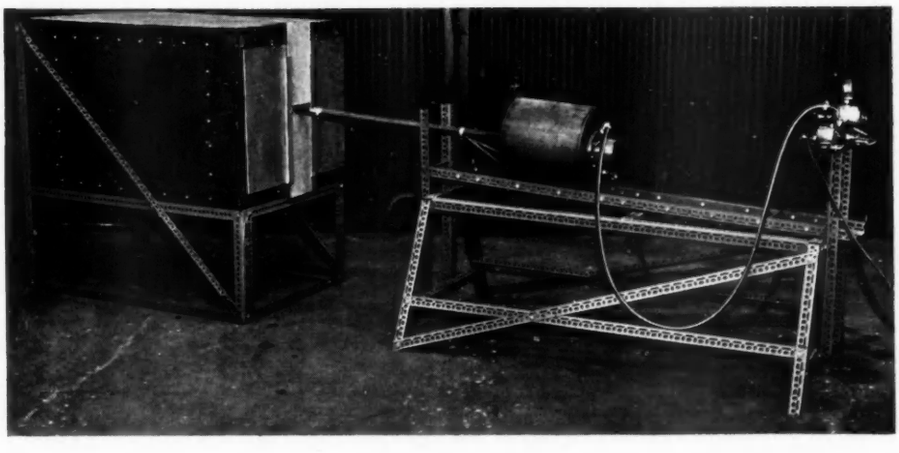
From the point of view of reliability and serviceability, the hot-gas system has the advantage; it is immune from stone and rain erosion, whereas the electrical system requires protection, and maintenance of the circuitry, controls, and alternators supplying the system are likely to be considerably heavier.

On existing aircraft with wing engines, the trend is to hot-gas ducts in the wings and cyclic electro-thermal de-icing for the tail surfaces. With the advent of rear-mounted engines, it seems possible that the electro-thermal system may gain in favour.

On the question of control of electro-thermal systems, there appear to be two schools of thought situated on opposite sides of the Atlantic. Opinion in the United States and Canada appears to favour a fully automatic and rather complex system, to achieve maximum efficiency on the control of parting-strip temperature, cyclic "off" time (in response to rate of ice build-up), and cyclic "on" time (in response to surface temperature, with over-riding time limit). British aircraft designers, on the other hand, adopt a less perfectionist, but simpler, approach, preferring thereby to control the cyclic time (in steps) with the ambient temperature; they show some reluctance even to incorporating protective switching to guard against accidental



(Left) Stone damage test rig—a catapult for throwing granite flints.

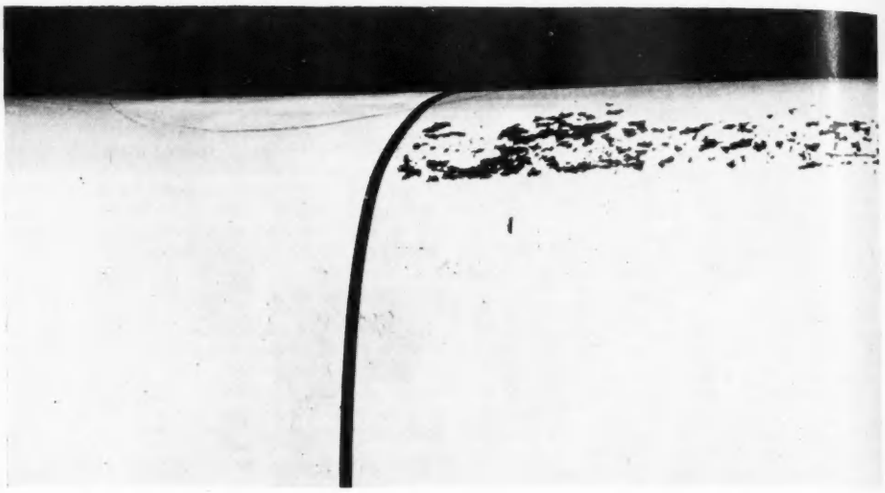


(Below) Hail damage test rig—a compressed air gun capable of throwing up to 1 in diameter synthetic hailstones at more than 500 m.p.h.

Continuing **Design**

overheating of the de-icer mats which, although unlikely in flight, can fairly easily be achieved if the system is switched on while the aircraft is standing on the ground.

Returning to the problem of rain, hail and grit erosion of electro-thermal de-icing mats: Napier, the makers of the widely used British "Spraymat" electro-thermal system, have carried out extensive research on this problem, and have evolved a satisfactory solution for speeds up to 450 m.p.h.—by applying a coating comprising an exceptionally heavy loading of a metal in resin. At higher speeds, this coating is still not effective against rain erosion. However, this problem, too, seems to be on the way to solution: developments in electroplating techniques have resulted in extremely hard yet flexible films resistant both to damage by stones thrown up from the runway and to heavy rain erosion. Formidable problems still remain in bonding the film to the heater mat surface without impairing its thermal efficiency.



Comparison of leading-edge areas, protected and unprotected by metal-loaded resin coatings, in hail condition.

ENGINE ICING PROTECTION

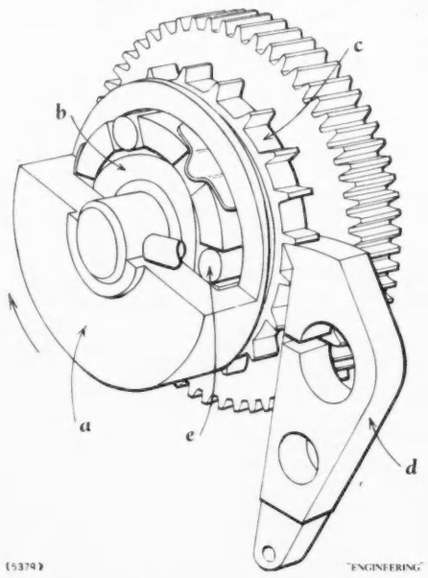
Wide publicity has been focused on the icing problems of the Bristol Proteus propeller turbine, now believed to be solved (ENGRG., 6 Dec. 57, p. 727). Although less has been heard about such troubles on Rolls-Royce engines they have, nevertheless, been experienced during development and there have been "no easy short cuts to the solution."

Their ultimate solution for axial compressor engines such as the Avon and Conway is to heat those engine and intake surfaces needing protection with hot air bled from the compressor. Before this solution was reached, however, they tried various methods: static and rotating hot-gas grids in front of the air intake, intended to heat all the air entering the engine to above 0° C, were far too costly in thrust losses and dead-weight. Freezing-point depressants, while giving some reduction of adhesion, were insufficiently effective and had gumming and corrosive propensities. Neither were PTFE coatings any help. Methanol and alcohol sprays into the intake, though very effective in suppressing ice build-up on rotor blades, cannot be used where compressor-bleed air is to furnish the cabin air supply; the weight of fluid is also a disadvantage. Eddy current heating for the rotor blades was also found to be too weighty. Momentum separation, using a gauze deflector screen in the intake, was theoretically attractive, but proved to give excessive thrust losses and also resulted in an unacceptable build-up of ice to the rear of the gauze guard.

On propeller turbine engines, such as the Dart and the Tyne, electro-thermal de-icing of the intake nose has been found to be the most economic and effective solution, electrical power already being available for propeller and spinner. One other possibility investigated by Rolls-Royce was an ice-scraping device known as "Boadicea's knife," consisting of an arm mounted on the spinner shaped to cut the ice off the leading edge of the intake. The lack of data on cutting angles for ice and the difficulty of practising in the machine shop would probably have led to trouble, but in any case the knife did sufficient damage on the ground without icing.

ROLLER CLUTCH FOR SMALLER MECHANISMS

A new type of roller clutch has been developed by Tiltman Langley Limited, Redhill Aerodrome, Surrey. Of robust design, the clutch is small, has a positive drive, and can be controlled mechanically or electrically; in the latter case, a suitable solenoid of 7 watt capacity can be used to operate the control pawl. The clutch is capable of transmitting about ½ h.p. at a speed of 1,500 r.p.m. It is designed to operate just as efficiently at − 40° C, or in tropical conditions, as it does under normal working temperatures.



The clutch is disengaged when the roller cage *c* is held stationary by the pawl *d*, the rollers then being prevented from being driven into the wedge formed by the housing (driver) and the driven cam.

The essential components of the clutch, shown in the accompanying illustration, comprise a housing *a*, which is, in fact, the driving member; a cam *b* attached to output gear; a control wheel *c*, which also forms the roller cage; a pawl *d*, and the rollers *e*.

In the illustration, which shows the clutch disengaged, the housing *a* is shown driving in a clockwise direction. In this condition, the control wheel *c* is held stationary by operation of the pawl *d*, thus preventing the rollers *e* from being driven into the wedge formed by the housing and cam.

If the control wheel is released, it is moved clockwise by the friction of the springs between the cage and the housing, and thus the rollers are driven into engagement. On stopping the control wheel, the rollers are kicked out of engagement and the clutch is disengaged.

There are various methods of mounting the pawl and solenoid in relation to the clutch control wheel, in order to provide different directions of rotation and to suit varying installation requirements.

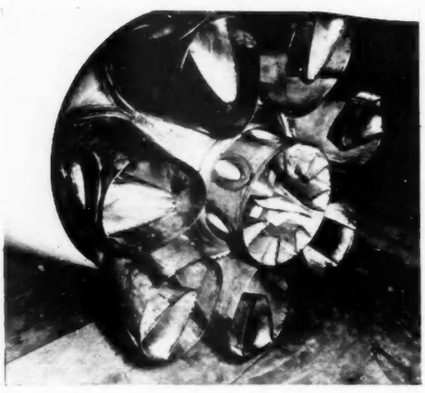
OLYMPUS TYPE TEST

An official type test at a static thrust rating of 17,000 lb has been successfully completed by a Olympus Mark 201 (B 01 7) turbojet, made by Bristol Aero-Engines Limited, Filton House, Bristol. The Olympus Mark 201 is claimed to have the highest thrust/weight ratio of any high-thrust turbojet which has completed an official type test. Highest power previously revealed for the Olympus was 16,000 lb thrust for the Mark 201 (B 01 6), which is now in production for the Avro Vulcan Mark 2 bomber.

ROLLS-ROYCE SILENCE AMERICAN AIRLINERS

The Douglas Aircraft Company have fitted noise suppressing nozzles of Rolls-Royce design to the Pratt and Whitney engines in the first D.C.8 airliner which was rolled out recently at their works at Santa Monica, California. This type of nozzle shown below is being used as an interim device until the Douglas Company's own exhaust equipment becomes available.

Production noise suppressors designed and made by Rolls-Royce are already fitted to the Avon engines of the de Havilland Comet, and those airlines which have specified Conway engines for their Boeing 707-420's will have Rolls-Royce suppressors incorporated in the complete engine pod which is being built by Rolls-Royce. In addition, the Boeing Company's own noise suppression equipment, which will be fitted to the other 707's, is based on Rolls-Royce research, for the Boeing and Rolls-Royce companies have an agreement to exchange all information on jet noise and its suppression.



Construction

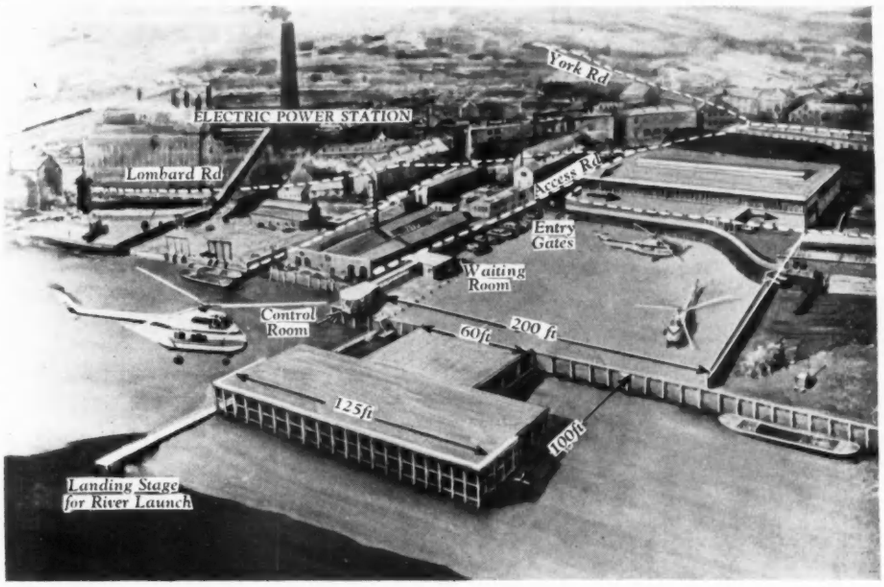
HELIPORT *for London's South Bank*

The Minister of Housing and Local Government has given permission to Westland Aircraft of Yeovil to build a temporary heliport in the centre of London. The site will be along the Battersea embankment of the River Thames and has been chosen as being "well-suited for experiment and development" with a helicopter service into the heart of the capital. In the letter giving his permission, the Minister observed that "while the noise of helicopters must cause some nuisance, it would be difficult to find a built-up area where noise was less likely to affect amenity." The Minister's decision has been given after a public inquiry which was referred to in Weekly Survey in our issue of 23 May (p. 642).

The proposed heliport is shown in the illustration. It is located on the south bank of the River Thames, 1,000 ft upstream from Battersea railway bridge and 2,500 ft downstream from Wandsworth road bridge, and more-or-less opposite Fulham Power Station. The site is surrounded on three sides by industrial buildings and is approached by a private roadway. By road, the heliport will be about four miles from Westminster Abbey or the Houses of Parliament.

The site consists of a clear space, roughly square, having an uninterrupted river frontage of about 200 ft. This will be used as an aircraft and car park, with necessary buildings located on one side. From this area it is proposed to construct a T-shaped landing platform over the river to be built on piles, steel braced with a reinforced concrete deck. The landing area will be 125 ft by 50 ft, the outer edge being 100 ft from the river bank. The approach leg will thus be 50 ft long and it will be 60 ft wide. Ancillary buildings will be added as necessary.

Westland are to apply for a Private User Licence in the first instance. It is intended, however, that the heliport should be available to all operators and the hours during which it will normally be manned will be advertised. During such hours only short notice of a request to land will be required, but special arrangements will be necessary at other times. Since the granting of permission to go ahead with the heliport, both BEA and Sabena have indicated their interest in operating charter flights from there.



Westland Aircraft are to establish a temporary heliport on the River Thames in London for an experimental helicopter service into the capital.

FORTH ROAD BRIDGE

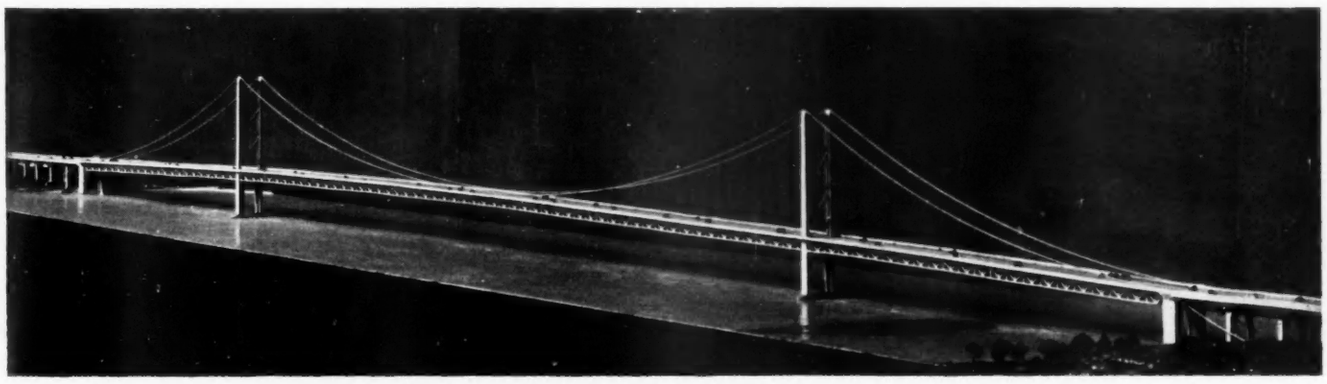
Tender for the Superstructure Pending

The first stages of the work for the foundations of the Forth road bridge have been begun. At the recent conversazione of the Institution of Civil Engineers, the consultants for the bridge exhibited a small-scale model (1 in to 100 ft) of the superstructure and released a number of details. The consultants are Mott, Hay and Anderson, of 9 Iddesleigh House, Caxton Street, London, S.W.1.

The model is illustrated on this page. Outside the United States the bridge will have the longest suspended span—3,300 ft—in the world. A clearance of 150 ft above high water has been allowed for shipping. The cables are supported by two main steel towers some 500 ft in height, thus making the dip in the cable (allowing for the depth of the main girders) of just over 300 ft. There are two 24 ft carriageways, two 9 ft cycle tracks and two 6 ft wide footpaths. To resist wind loading the stiffening trusses are to be 27 ft 6 in deep; there are also to be wind bracing frames in the top and bottom chords to provide torsional stiffening and assist in giving aerodynamical stability.

The deck is to be at the level of the upper stiffening frame. For the section between the towers, to give lightness of construction, the deck is said to be of steel (no mention is made of any road surfacing); along the tail spans—each 1,340 ft long—where weight does not give rise to expensive construction, a reinforced concrete deck resting on steel stringers is to be used. The deck is suspended by wire rope hangers of about $1\frac{3}{4}$ in diameter from two main cables of 24 in diameter made up of 12,000 high tensile steel wires 0·196 in in diameter; no details have been given of the lay to be adopted for the wires. The cable ends are also supported by the last of the reinforced concrete piers carrying the approaches and are anchored in tunnels in the rock.

The bridge—like many others such as the Severn and Humber crossings—has a long background. The Forth road bridge was certainly proposed in 1923, if not before; the consultants (the same as now) were appointed and the cost was put at £4 million. In the five years following 1926 four sites were examined: (1) about 1 mile upstream of the railway bridge; (2) alongside the railway bridge on the downstream side; (3) about 1 mile downstream of the railway; and (4) about $\frac{1}{2}$ mile upstream on the Mackintosh Rock site. It is this fourth site that has now been adopted. For many years



Model of the Forth road bridge—to have the longest suspended span in the world outside the USA.

Continuing Construction

railway interests successfully delayed the opening of a direct road route into north-east Scotland. After the war the cost had risen to £6,200,000. and the Government shied at the cost. Various alternatives were then examined, particularly a tube laid on the estuary bed, and Sir Bruce White's suggestion of a light-alloy road deck built through the existing bridge above the railway. After stating in 1955 that the crossing would be started, by bridge or tunnel, "within four years," the Government last year announced that work would be begun on the bridge during the summer of 1958. And it has. The cost is put at £15 million.

Earlier this year it was announced that negotiations had been begun with a consortium of three nominated contractors for the main superstructure. The firms concerned to date are Sir William Arrol and Company, Cleveland Bridge and Engineering Company, and Dorman Long (Bridge and Engineering). Their tender is expected to be submitted during the next few weeks and it is to be expected that it will be accepted during the late autumn or at least before the end of the year. Division of the work between the contractors is likely to be that Dorman Long will do the heavy girder work and the stiffeners, Cleveland Bridge the chains and hangers, and Arrol's the towers.

Some estimated quantities for the bridge are as follows:—

Towers	6,000	tons steelwork
Suspended structure	16,000	,, ,,
Cables	8,000	,, steel wire
Reinforcement ..	6,000	,, steel rod
Other steel	3,000	,,
Total steel ..	39,000	tons

Concrete for the main bridge, including the approach spans but not the approach roads, is estimated to be 147,000 cu. yd. There will be a number of minor bridges, including a flyover, in the 12 miles of approach roads. The viaducts (of reinforced concrete) involve 17 spans of which the longest is 170 ft.

WOOD-FIBRE BUILDING BOARDS

Two 35 mm and 16 mm colour films with sound commentary explaining the uses of their building hardboards were recently shown in London by the Building Boards Division, Bowaters Sales Company Limited, Bowater House, Stratton Street, London, W.1. The first, an animated cartoon film, "All Aboard," deals amusingly in 10 minutes with the raw materials, manufacturing processes and applications, in building and in industry, of Bowater Board. The second is a documentary film, "Phoenix City," running for 19 minutes and showing the part played by the firm's insulation board and metal-fixing systems both in the industries for which the city of Coventry is traditionally famous and in the new buildings erected to replace those destroyed by enemy action during the war.

Composed of highly-compressed and treated wood fibres the boards can be cut, punched, drilled and bevelled without fear of splitting, splintering or cracking. In addition to the "standard" and "super" hardboards, "perforated," "leather-grained" and "reeded" qualities are available. Thermal-insulation and sound-absorption boards, and acoustic panels are also produced.

Engineering at Home

MORE LINES FOR TV?

Experiments described in a paper, "The Relation Between Picture Size, Viewing Distance and Picture Quality," by L. C. Jesty, suggest that present European standards of television are wasteful of bandwidth. If this is true, sets could be made more cheaply, as simpler circuits are required for smaller bandwidths. Alternatively, use could be made of the excess bandwidth to improve the quality of the picture, for example, to increase the number of lines used to make up a picture from 405 to 625. There is already some evidence that people are complaining of the picture "lininess" on 21 in black-and-white receivers in this country, and that this size is about the limit for a 405 line system viewed in the larger size living room. On the basis of his experiments, Mr. Jesty considers that a change to 625 lines would allow the picture size to be increased to that of a 29 in tube, and for 819 lines, to at least 34 in.

The initial experiments of the series were concerned with the distance that a viewer chose to sit from his screen. Sharply focused pictures from a colour slide projector were thrown on to screens of various heights. The ratio of picture width to height was maintained at 4 : 3. It was found that viewers chose a preferred distance from the screen of 4·1 times the picture height. When the pictures were defocussed slightly, viewers chose to sit at 6·8 times the picture height. One can sit closer to a good quality picture.

A second set of experiments was devised to obtain the relation between viewing distance and picture sharpness. In the course of these, both optical projectors and closed circuit television were used. Basically, the lininess of the television picture and the restriction of the bandwidth of the television signal correspond to the defocussing of the slide projector. In the television picture, the number of lines decides the vertical resolution and the bandwidth decides the horizontal resolution. Various assumptions are made as to the best ratio of horizontal resolution to vertical resolution, for the normal television picture with a width-height ratio of 4 : 3.

The experiments showed that, in effect, a subject viewing the present television system used the lininess of the picture as a criterion of his distance from the screen. And the distance chosen is such that part of the horizontal detail is missed. In fact, the results obtained allow the calculation of the optimum bandwidth for a given number of lines: for 405 lines, it is just over 1 Mc/s, whereas in practice about 3 Mc/s are used. Although there is still some advantage to be gained from the increased bandwidth, it is not nearly so much as would be gained by increasing the number of lines as well.

Techniques such as spot wobble make the lines on the screen less noticeable, and so allow the viewer to move closer and enjoy more of the horizontal detail. Synchronous spot wobble, in particular, permits an increase in vertical resolution. However, only preliminary results have been obtained with these techniques.

As a point of interest, the author points out that his experiments indicate that a maximum of 8·5 Mc/s is required to produce a television picture equal in quality to a 35 mm cinema picture. On the basis of similar reasoning, a Todd-AO picture would require 38 Mc/s maximum, and Cinerama, 60 Mc/s.

In the present British television system, there appears to be about 50 per cent of the bandwidth available for improvement of the picture quality, and, says the author, its best use requires consideration. The following alternatives have been suggested: to investigate the possibility of increasing the apparent picture sharpness by receiver display storage, for example, using an afterglow screen; to insert colour into the upper end of the video frequency band, but without interleaving; to increase the number of lines from 405 to 625; to increase the picture ratio from 4 : 3 to 2 : 1; or to allow the receiver manufacturers to produce a cheaper receiver.

POLYTHENE COLD-WATER TUBING SPECIFICATION

In order to meet a requirement for a practical guide in the increasing use of high-density polythene in the manufacture of tubing for cold-water services, a technical committee of the British Plastics Federation, 47-48 Piccadilly, London, W.1, have prepared and issued a specification (price 1*s*.) on the subject.

The composition of the material is closely defined and the only additives specified are those which have been approved by the Ministry of Food. An additional safeguard is provided by a stress rupture test at 80° C, to be conducted under closely controlled conditions. It is stipulated that the internal and external surfaces of the tubes shall be smooth, clean and reasonably free from grooves and other defects, and for the convenience of architects, builders and plumbers, the tubes are to carry informative indelible markings at intervals throughout their lengths.

Adequate wall thicknesses have been specified with due regard to the advantageous properties of the material and it is emphasised that the conditions laid down in the hydraulic and tensile tests are such that users can have the highest confidence in high-density polythene for cold-water services.

GUN MICROPHONE

A gun microphone, so-called because it is about 3 ft long and looks like a gun barrel, is being used experimentally by the BBC. The microphone was developed in Germany and for some months past the BBC have been studying its applications. It was used at a by-election meeting, for example, and allowed the television viewers to hear members of the audience—particularly the hecklers—clearly, without the usual interview microphones being carried about on long leads.

The advantage for television is that sounds can be pinpointed without a microphone appearing on the screen. The "gun" can be mounted on a camera so that all the operator has to do is train the camera on a speaker and the microphone will be automatically focused on his voice.

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